Environmental radioactivity in Denmark in 1973

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A. Aarkrog and J. Lippert

Danish Atomic Energy Commission
Research Establishment Risø
Health Physics Department

UDC 614.73 (489)

Abstract

The present report deals with the measurement of fall-out radioactivity in Denmark in 1973. Strontium-90 was determined in samples from all over the country of precipitation, soil, ground water, stream and lake water, sea water, grass, dried milk, fresh milk, grain, bread, potatoes, vegetables, fruit, total diet, drinking water, and human bone. Furthermore ^{90}Sr was determined in local samples of air, rain water, grass, sea plants, fish, and meat. Caesium-137 was determined in soil, sea water, milk, grain products, potatoes, vegetables, fruit, total diet, and meat, and ^{137}Cs was measured by wholebody counting in persons from a control group at Risø. Estimates of the mean contents of radiostrontium and radiocaesium in the human diet in Denmark in 1973 are given. The γ-background was measured regularly at locations around Risø, at ten of the State experimental farms and in an area in Zealand, one in Jutland where future nuclear power plants might be located, and along the shores of the Great Belt. Finally the report includes, as previously, regular surveys of environmental samples from the Risø area.

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CONTENTS

ABBREVIATIONS AND UNITS

FP	Fission products
pCi	picocurie, 10^{-12} Ci, µµCi
nCi	nanocurie, 10^{-9} Ci, mµCi
mCi	millicurie, 10^{-3} Ci
MPC	maximum permissible concentration
c/min	counts per minute
d/min	disintegrations per minute
c/h	counts per hour
µR	micro-roentgen, 10^{-6} roentgen
S.U.	pCi ^{90}Sr/g Ca
O.R.	observed ratio
M.U.	pCi ^{137}Cs/g K
V	vertebrae
m	male
f	female
n Sr	natural (stable) Sr
eqv. µg U	equivalents µg uranium: activity as from 1 µg U (~ 90 d/h)
eqv. mg KCl	equivalents mg KCl: activity as from 1 mg KCl (~0.88 d/min)
S.D.	standard deviation: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{(n-1)}}$
S.E.	standard error: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{n(n-1)}}$
U.C.L.	upper control level
L.C.L.	lower control level
Δ	one standard deviation due to counting
S.S.D.	sum of squares of deviation: $\Sigma(\bar{x}-x_i)^2$
f	degrees of freedom
s^2	the variance
v^2	the ratio between the variance in question and the residual variance
P	probability fractile of the distribution in question
η	coefficient of variation, relative standard deviation
anova	analysis of variance
A	relative standard deviation 20-33%
B	relative standard deviation >33%, such results are not considered significant different from zero activity

Samples:

H:	sea water
J:	soil
L:	air
B:	bed soil
Å:	eel
PG:	grass
PH:	sea plants
D:	drain water
S:	waste water
R:	precipitation
M:	milk

1. INTRODUCTION

1.1.

The present report is the seventeenth of a series of periodical reports (cf. ref. 1) dealing with measurements of radioactivity in Denmark.

The programme is nearly unchanged as compared with 1971. We have however cut down the number of sample locations for fresh milk, total food and bread to one town in each of the eight zones compared with six towns previously. The sampling in Copenhagen continues.

1.2.

The methods of radiochemical analysis[2-4] and the statistical treatment of the results[5] are still based on the principles established in previous reports[1].

1.3.

The report does not include detailed tables of the total β-measurements from the environmental control of the Risø site. These tables are available in the form of microcards at the library of the Danish Atomic Energy Commission at Risø.

1.4.

The report contains no information as regards sample collection and analysis except in the cases where these procedures have been altered.

1.5.

In 1973 the personnel of the Environmental Control Section of the Health Physics Department consisted of one chemist, ten laboratory technicians, two sample collecters, and two dishwashers. As in previous years, important assistance was rendered by the Section for Electronics Development, not only in the maintenance of the counting equipment, but also in the interpretation of the γ-spectra. The programme (cf. 2) used in the calculations of ^{90}Sr and the γ-analysis as well as the program for data treatment[x] were developed by the Section for Electronics Development.

1.6.

The composition of the Danish average diet used in this report is identical with that proposed in 1962 by Professor E. Hoff-Jørgensen, Ph. D.

2. ORGANIZATION AND FACILITIES[1, 6, 7, 8]

We now have 3 Ge(Li)-detectors each connected to a 1024-channel analyzer. The 8 inch NaI(TL) detector used for whole body measurements and 4 detectors for alpha spectrometry are connected to a forth 1024 channel analyzer.

A computer program STATDATA 16 for the treatment of the results of this report (and results from several other projects) is under development. The program will check and store the data, produce lists, tables and plots and call separate programs for analysis of variance and regression etcetera. The principle for the registration of data is an assignment of 6 parameters to each result or set of multiple results. The parameters used are:

Isotope (or code for γ-background etc.)
Sampling date
Sample specimen type
Sampling location
Quality of measurement (relative standard deviation)
Unit of results

followed by:

Number of results
Results.

Up to now approximately 15000 sets of results have been registered covering the period from 1957; a similar number of results, however, is still unregistered. A detailed description of the program will be published later.

3. RISØ ENVIRONMENTAL MONITORING IN 1973

3.1. Gross β-Activity

3.1.1. Sea Water

Fig. 3.1.1.1 shows the sample locations in Roskilde Fjord. Fig. 3.1.1.2 shows the control chart for H I. The yearly mean for H I in 1973 was 55 eqv. mg KCl/2.5 g (in 1972: 56), for H III-VI: 55 eqv. mg KCl/2.5 (in 1972: 58) and for H VII-X: 56 eqv. mg KCl/2.5 g (in 1972: 56). Fig. 3.1.1.3 shows the mean levels of radioactivity in sea salt since 1957.

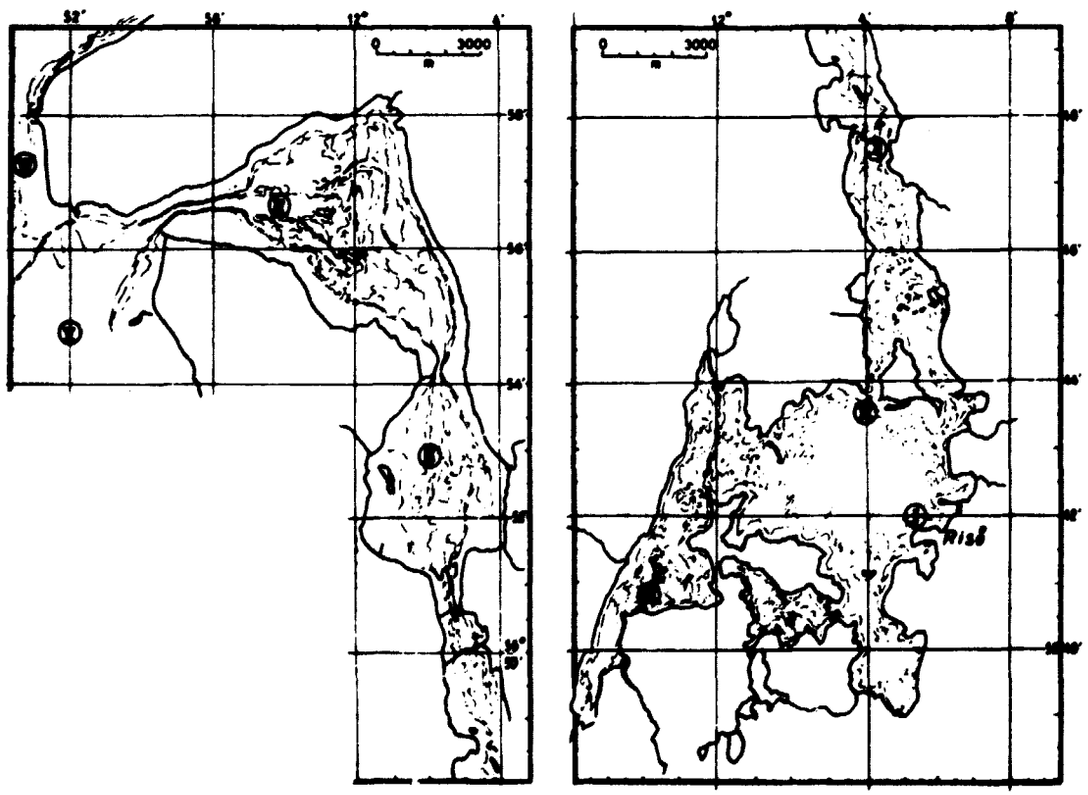


Fig. 3.1.1.1. Roskilde Fjord.

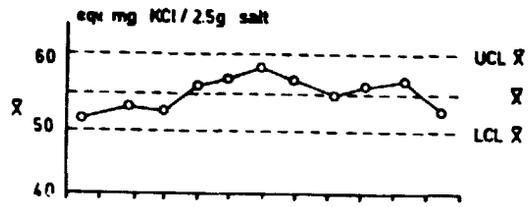
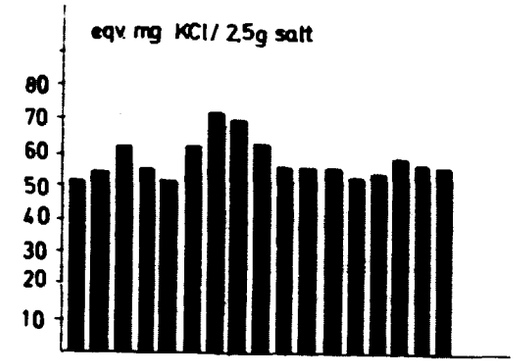
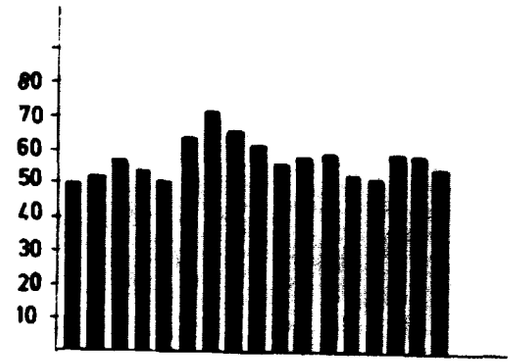


Fig. 3.1.1.2. Control chart for HI, 1973





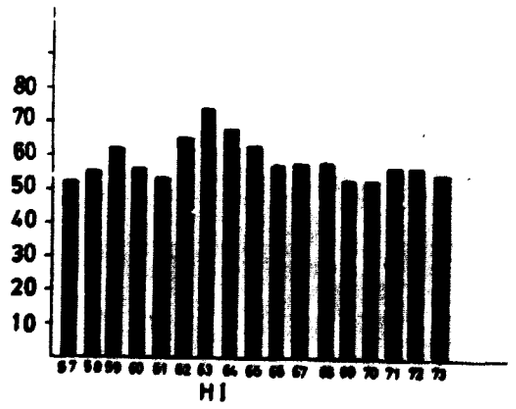


Fig. 3.1.1.3. Mean radioactivity in sea water, 1957-73

3.1.2. Soil

Figs. 3.1.2.1 and 3.1.2.2 (the coloured map) show the sample locations for land samples in the environment of Risø.

The yearly mean for J I in 1973 was 131 eqv. mg KCl/3.0 g soil (in 1972: 138), for J II-III: 130 eqv. mg KCl/3.0 g (in 1972: 140). Fig. 3.1.2.3 shows the mean levels of radioactivity in soil since 1957. J IV-V were not sampled in 1973. Since July 1973 the soil programme has been replaced by γ-background measurements (cf. 8.4.2).

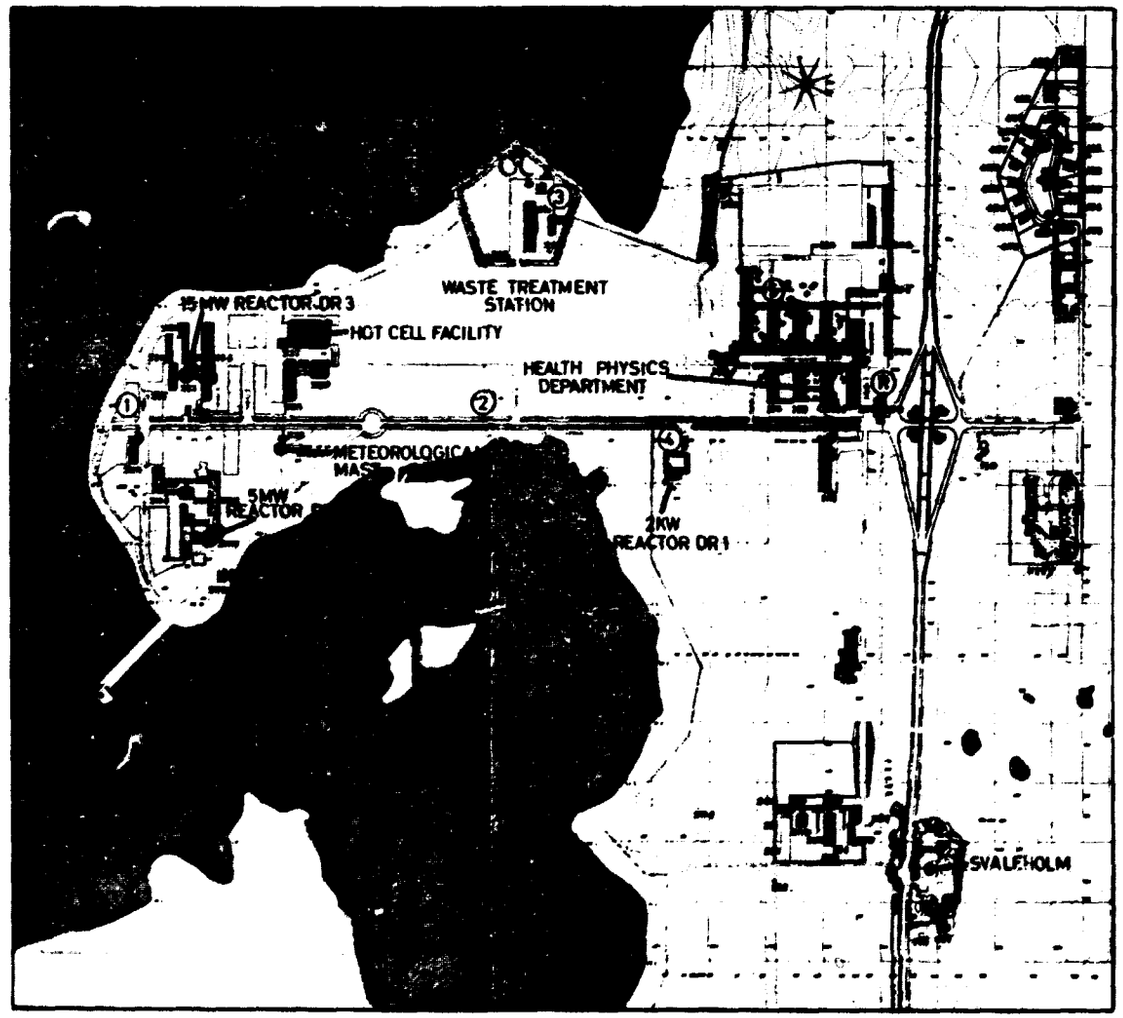


Fig. 3.1.2.1. The Risö Research Establishment.

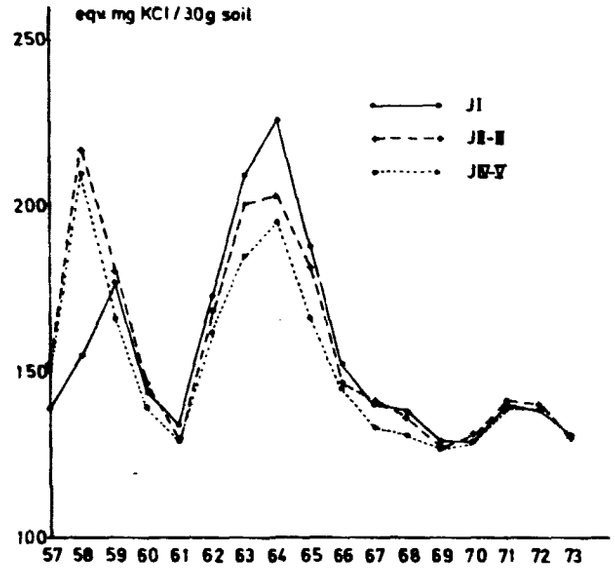


Fig. 3.1.2.3. Mean radioactivity in soil, 1957-73

3.1.3. Air

Fig. 3.1.3.1 shows the diagram for FP activity in air samples in 1973. The mean value for the year was 0.08 eqv. mg KCl/m^3 as compared with 0.20 eqv. mg KCl/m^3 in 1972.

Fig. 3.1.3.2 shows the mean FP levels in air since 1957.

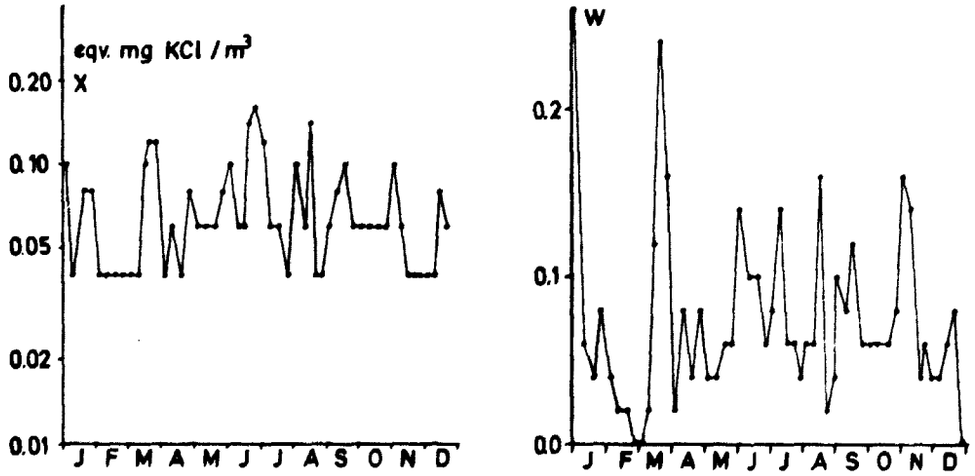


Fig. 3.1.3.1. Control chart for LF, 1973

Fig. 3.1.3.2. Mean radioactivity in air, 1957-73

3.1.4. Bed Soil From the Fjord

The mean activity in bed soil B I was 160 eqv. mg KCl/3.0 g ash in 1973 as compared with 134 eqv. mg KCl/3.0 g in 1972. Fig. 3.1.4.1 shows the mean levels for B I since 1957 (cf. also 3.4).

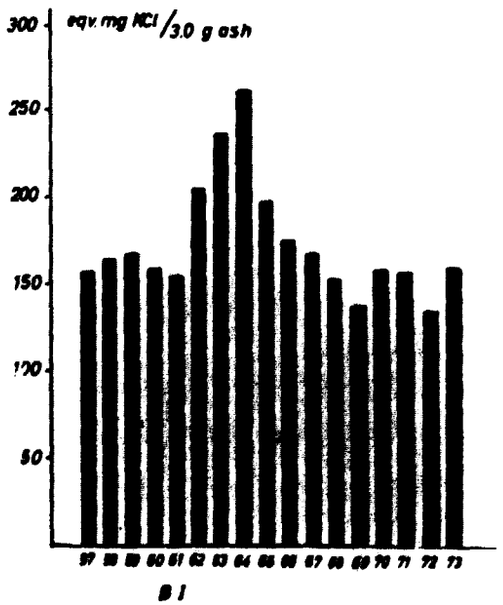


Fig. 3.1.4.1. Mean radioactivity in bed soil, 1957-73

3.1.5. Fish

No fish samples from Roskilde Fjord were measured for total β-activity in 1973.

3.1.6. Grass

The mean values were in 1973 for PG I: 7 eqv. mg KCl/0.1 g grass ash (in 1972: 21), for PG II-III: 4 eqv. mg KCl/0.1 g (in 1972: 15) and for PG IV-V: 14 eqv. mg KCl/0.1 g (in 1972: 14). Fig. 3.1.6.1 shows the mean activities in grass ash since 1957.

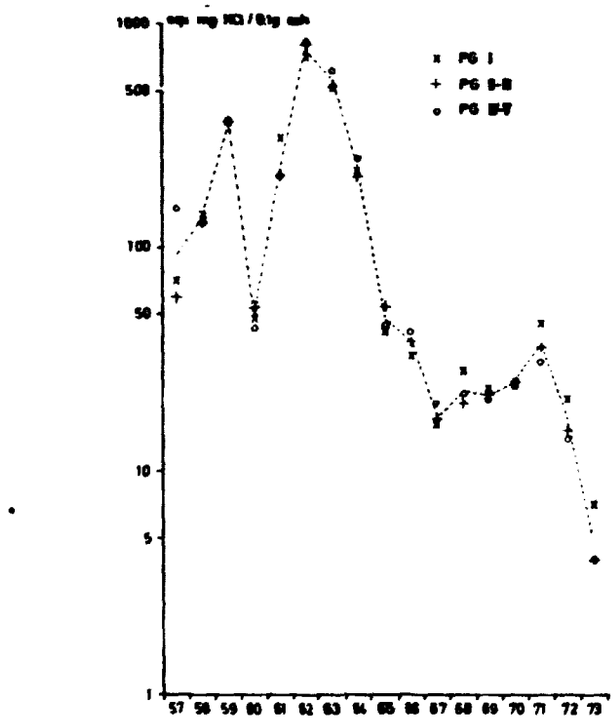


Fig. 3.1.6.1. Mean FP-radioactivity in grass ash, 1957-73

3.1.7. Sea Plants

The mean FP level in 1973 in Fucus vesicolosus (PH I) was 12 eqv. mg KCl/0.1 g ash (6 in 1972). In Zostera marina (PH III-IX) we found 2 eqv. mg KCl/0.1 g ash in 1973 (2 in 1972).

3.1.8. Fresh Water

Fig. 3.1.8.1 shows the control chart for S (cf. fig. 3.1.2.2). The yearly means for D I, D II, D IV, and S in 1973 were 49 eqv. mg KCl/l (1972: 24), 14 eqv. mg KCl/l (1972: 14), 38 eqv. mg KCl/l (1972: 17), and 31 eqv. mg KCl/l (1972: 37) respectively. Fig. 3.1.8.2 shows the activity in drainage water (D) and sewage water (S).

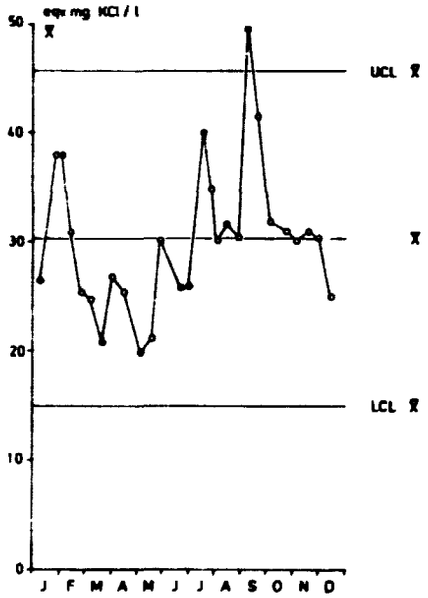


Fig. 3.1.8.1. Control chart for sewage water (S), 1973

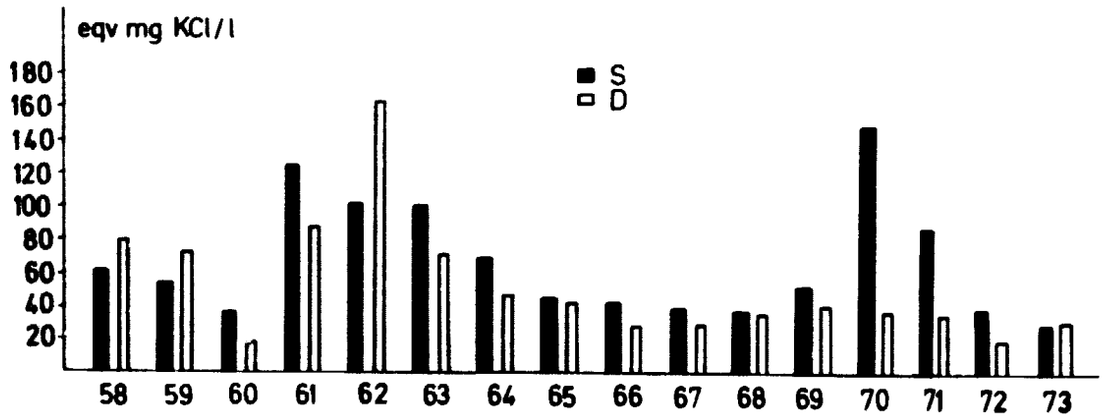
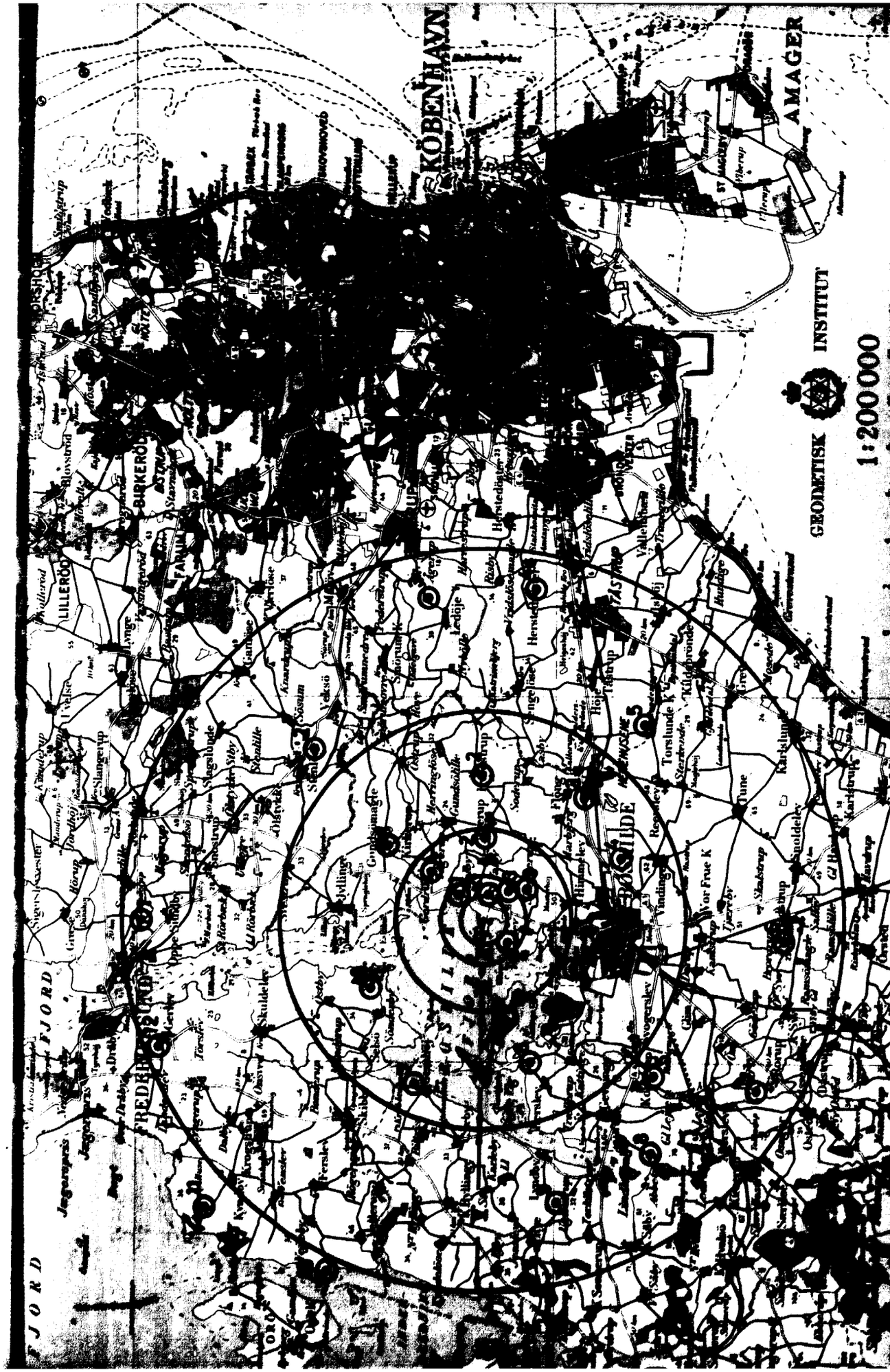


Fig. 3.1.8.2. Mean radioactivity in fresh water, 1958-73

3.1.9. Rain Water

Figs. 3.1.9.1 and 3.1.9.2 show the specific FP level in and the total fall-out from rain water collected daily at Risø in 1973. The total fall-out in 1973 was measured at $0.017 \cdot 10^6$ eqv. mg KCl/m^2, and the annual mean



concentration in rain water at Risø was 30 eqv. mg KCl/l. In 1972 the corresponding figures were $0.031 \cdot 10^6$ and 67 respectively.

Fig. 3.1.9.3 shows the specific activity in rain water since 1957.

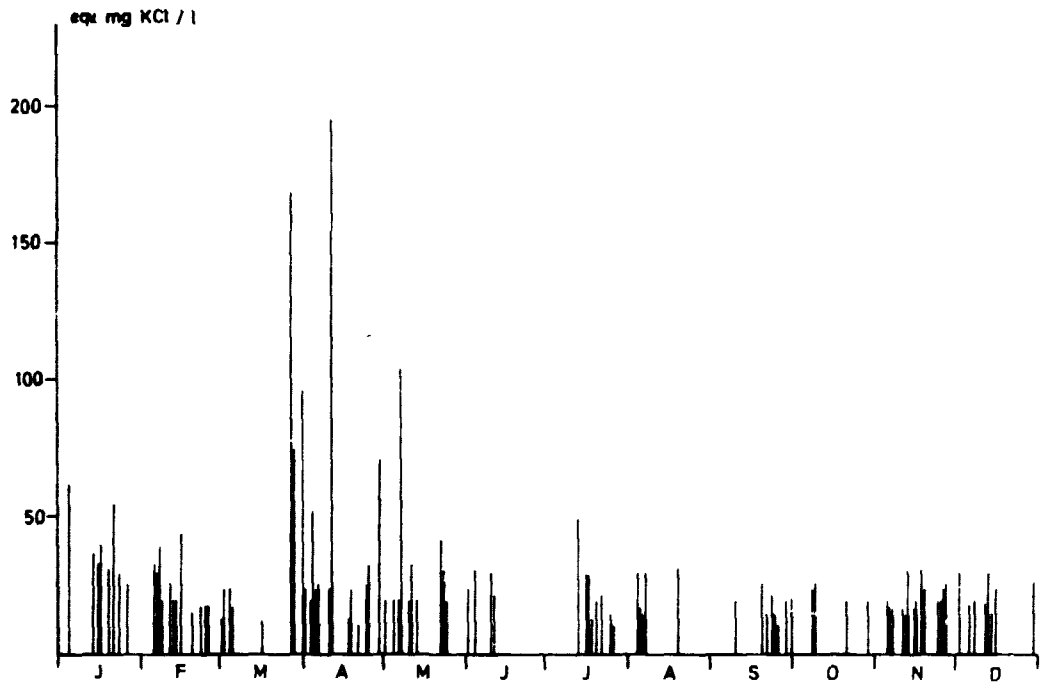


Fig. 3.1.9.1. Concentration of β-activity in precipitation in 1973

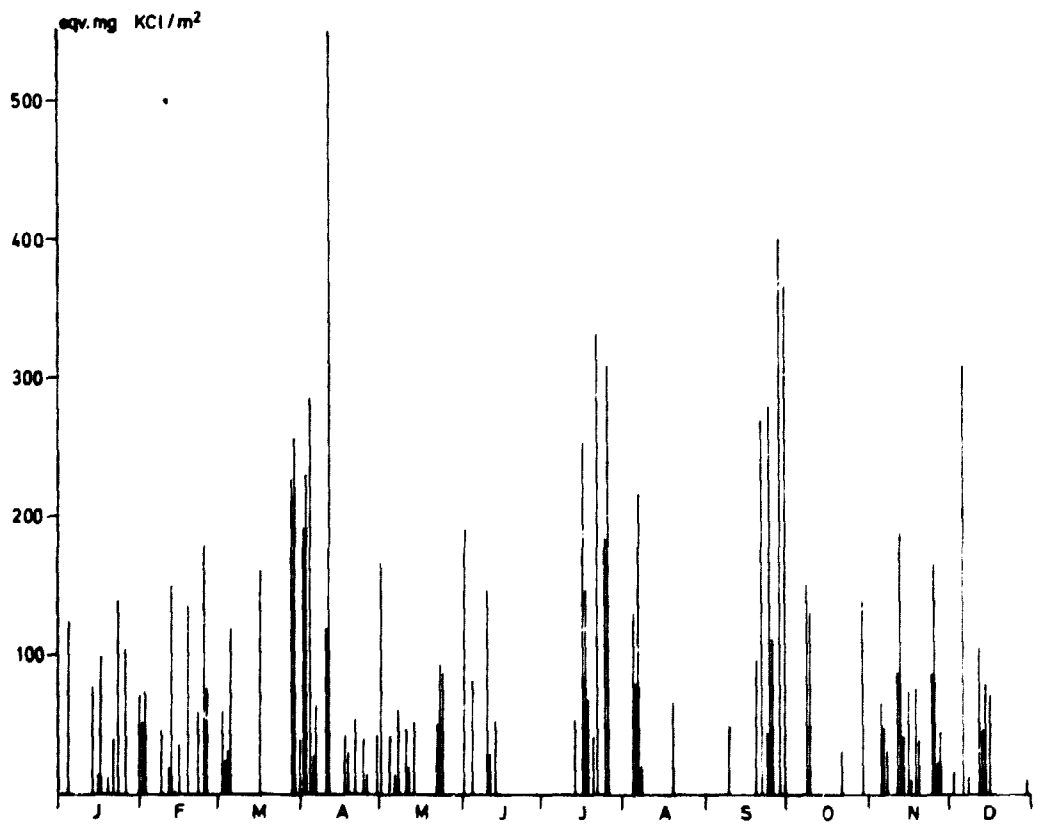


Fig. 3.1.9.2. Total fall-out from precipitation in 1973

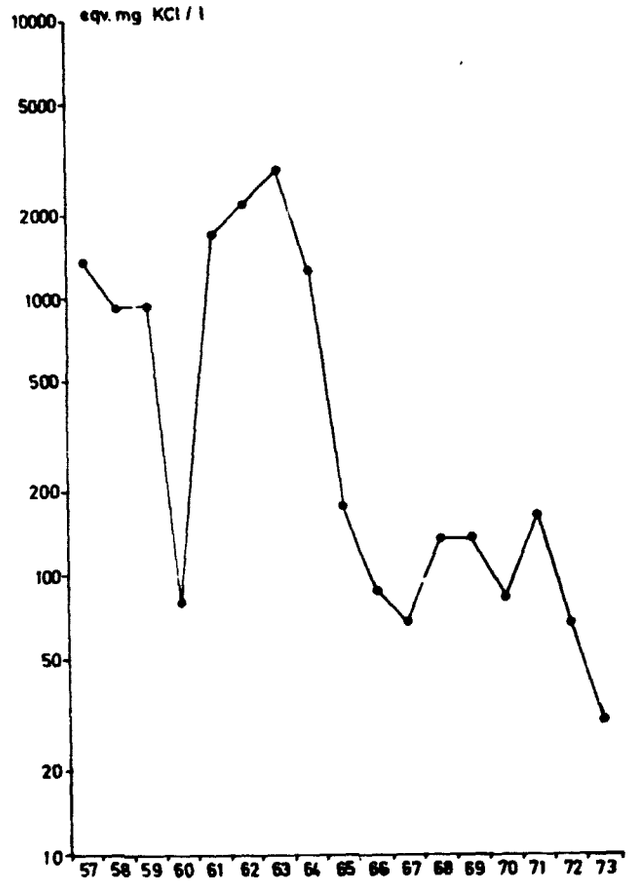


Fig. 3.1.9.3. Specific activity in precipitation, 1957-73

3.2. Radiochemical β-Analysis

3.2.1. Air

The "big air sampler" described in Risø Report No. 23[1] has a shunt through which we determine the air volume. As in 1971 and 1972 we analysed both the shunt filter (I) and aliquots cut out from the main filter (II) to see whether the activity levels were the same in the two filters. As I/II = 1.22 ± 0.16 (1 SE), we conclude as in 1971 and 1972 that the two filters showed the same levels. We shall report the mean air activity level for 1973 as the mean of the two monthly glass-fibre filter collections and the daily paper filter sampling: 0.39 ± 0.01 pCi $^{90}Sr/10^3m^3$, i.e. 50% of the 1972 level. The mean peak activity of the three collections in 1973 was measured in June to be 0.63 pCi $^{90}Sr/10^3m^3$.

Fig. 3.2.1.1 shows the ^{90}Sr levels in air since 1957.

Table 3.2.1

Strontium-90 in air collected at Risø in 1973
pCi $^{90}Sr/10^3m^3$

Month	Daily air filters Paper	Monthly air filters (glass-fibre filters) I	II
Jan.	0.24	0.24	0.19
Feb.	0.32	0.28	0.24
Mar.	0.55	0.45	0.43
Apr.	0.49	0.40	0.43
May	0.66	0.62	0.39 A
June	0.71	0.67	0.51
July	0.53	0.63	0.24 A
Aug.	0.44	0.37	0.47
Sep.	0.23	0.29	0.20
Oct.	0.24	0.26	0.18
Nov.	0.27	0.26	0.38
Dec.	0.24	0.25 B	0.66
1973	0.41	0.39	0.36

I: are the normally used shunt filters.

II: are aliquots cut out from the main filters also used for ^{137}Cs determination (cf. table 3.3.1).

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

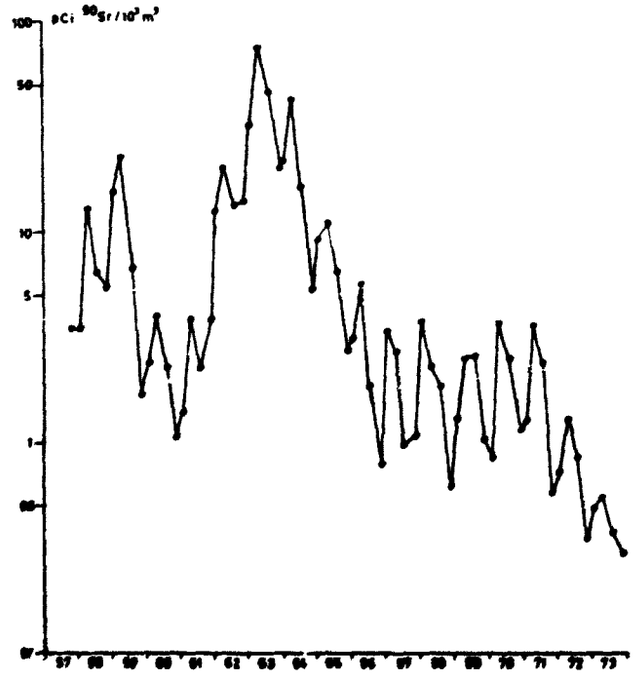


Fig. 3.2.1.1. Quarterly ^{90}Sr levels in air, 1957-73

3.2.2. Grass

Table 3.2.2 shows the ^{90}Sr content in grass ash from Zealand in 1973. The mean ^{90}Sr activity was 2.1 pCi ^{90}Sr/g ash or 34 S.U. as compared with 2.6 pCi/g ash or 46 S.U. in 1972, i.e. the 1973 level was approx. 70% of the 1972 level. Fig. 3.2.2.1 shows the ^{90}Sr levels in grass since 1957.

Table 3.2.2

Strontium-90 in grass from Zealand, 1973

	pCi ^{90}Sr/g ash	pCi ^{90}Sr/g Ca
Jan.-Mar.	1.89	37
Apr.-June	1.95	37
July-Sep.	2.25	33
Oct.-Dec.	2.23	29
Mean	2.08	34

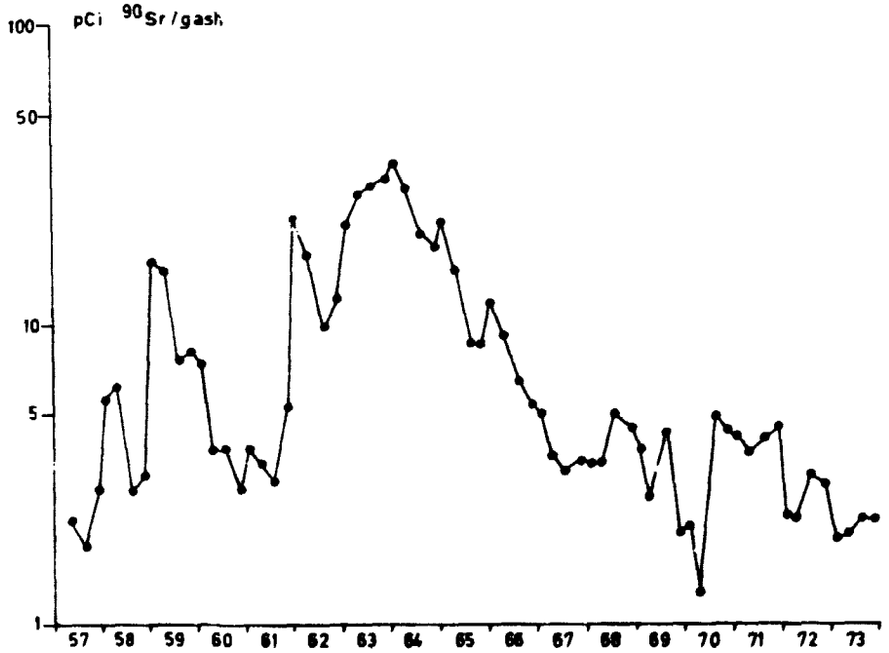


Fig. 3.2.2.1. Quarterly ^{90}Sr levels in grass ash, 1957-73

3.2.3. Sea Plants

Fig. 3.2.3 shows the S.U. levels in sea plants since 1959 and table

3.2.3 the results for 1972. The level in Fucus vesicolosus was 21 pCi ^{90}Sr/g Ca, and in Zostera marina we found 3 pCi ^{90}Sr/g Ca.

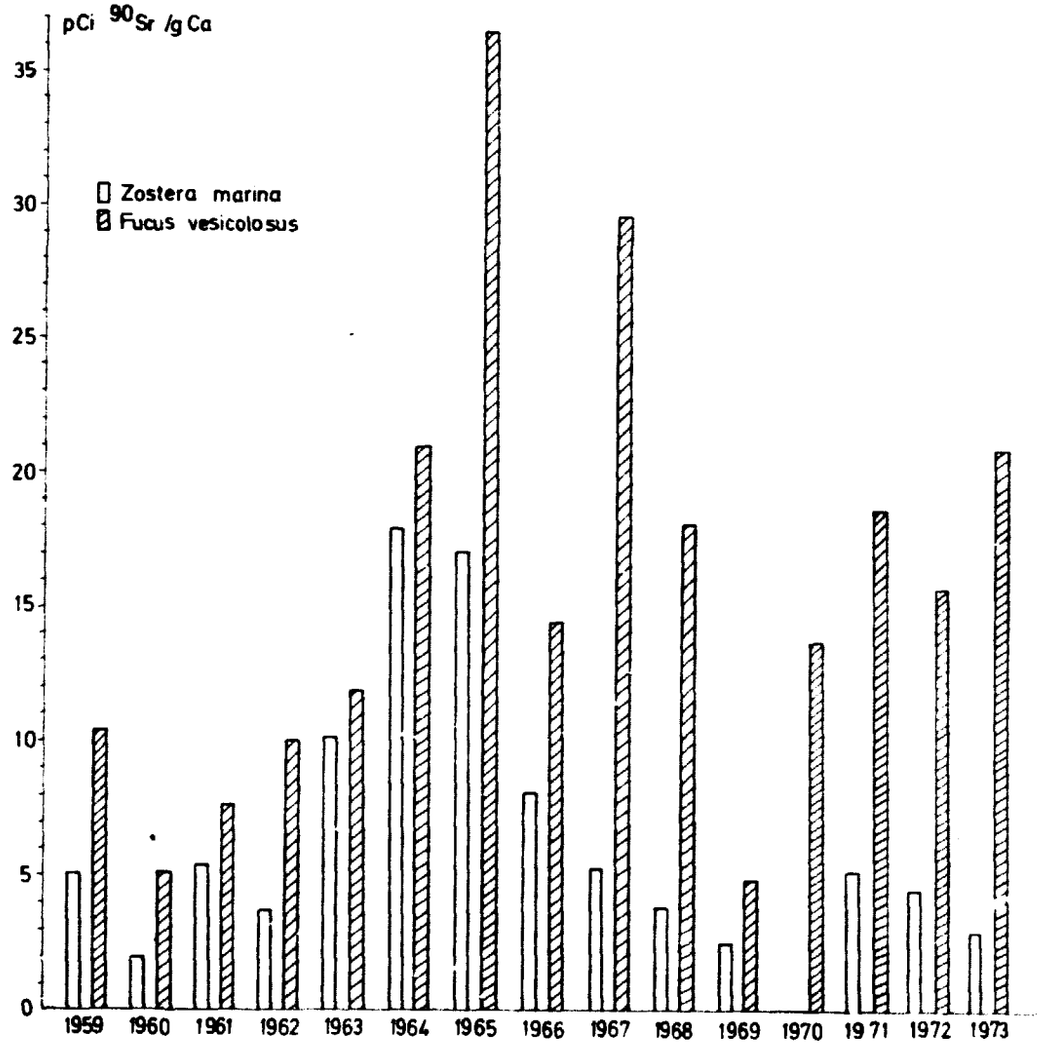


Fig. 3.2.3. Strontium-90 in sea plants from Roskilde Fjord, 1959-73

Table 3.2.3

Strontium-90 in sea plants from Roskilde Fjord in 1973

	Location	Species	pCi ^{90}Sr/g Ca	pCi ^{90}Sr/g ash	mg Sr/g Ca
July	pH III	Zostera marina	2.8	0.18	13.1
July	pH IX	Zostera marina	5.7	0.31	17.2
July	pH I	Fucus vesicolosus	20.8	1.86	36.5
Sep.	pH III	Zostera marina	2.8	0.35	11.3
Sep.	pH IX	Zostera marina	1.3	0.19	8.6

3.2.4. Rain Water

Table 3.2.4.1 shows the quarterly radiostrontium level in rain water collected at Risø in 1973. The total ^{90}Sr fall-out in 1973 was 0.10 mCi $^{90}Sr/km^2$ (551 mm precipitation), and the mean concentration in the rain water was 0.18 pCi $^{90}Sr/l$. In 1972 we measured 0.34 mCi $^{90}Sr/km^2$ (467 mm precipitation and 0.7 pCi $^{90}Sr/l$, i.e. the 1973 levels were 27% of the 1972 figures.

Fig. 3.2.4.1 shows the ^{90}Sr levels in rain water since 1959.

At five sampling locations (1-5) in zone I (cf. fig. 3.1.2.1) ion-exchange columns collected monthly samples of precipitation along with the bottle collectors. The columns have been described earlier (Risø Report No. 41 [1]) and are similar to those used in the U.S.A. by HASL[4]. The purpose of this collection is to compare the efficiency of the ion-exchange columns with that of rain bottles as collectors of fall-out. Table 3.2.4.2 shows the results. Further more rain bottles have collected precipitation in 8 different heights between groundlevel and 120 metres (cf. 8.1). The total amount of ^{90}Sr fall-out in 1973 measured by the 3 systems were: 0.10 mCi $^{90}Sr/km^2$, 0.15 and 0.15 respectively.

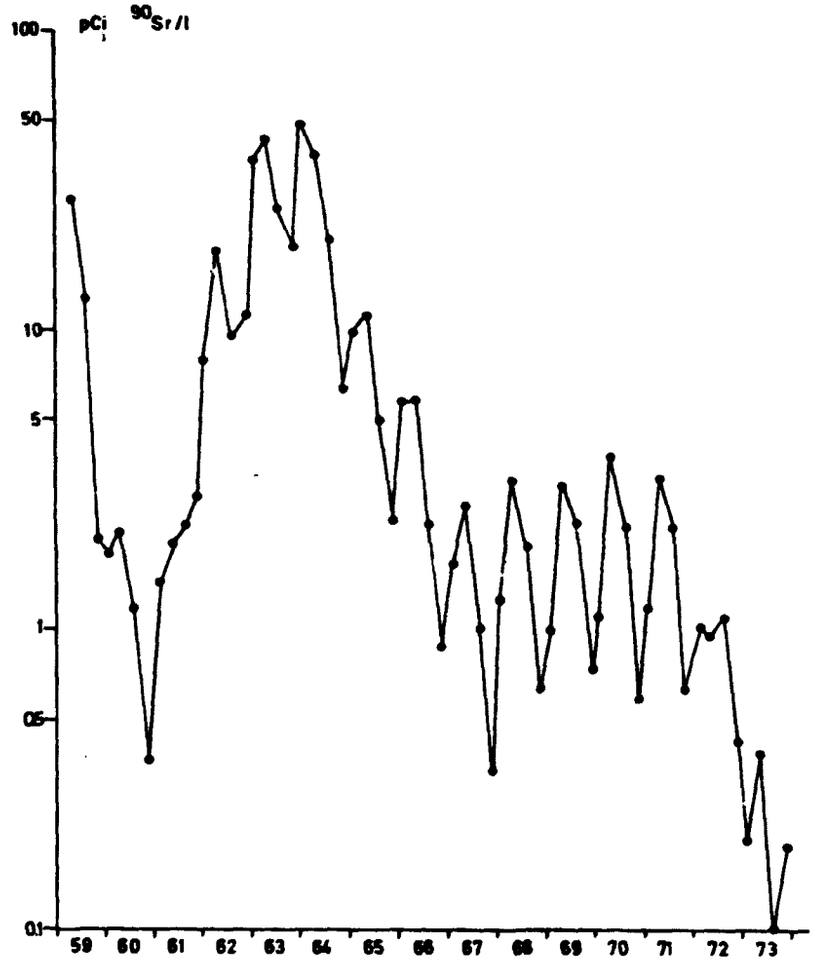
Table 3.2.4.1

Strontium-90 in rain water collected in rain bottles at Risø in 1973 (sampling area 0.236 m^2)

Month	mm	pCi $^{90}Sr/l$	mCi $^{90}Sr/km^2$
Jan., Febr., Mar., Apr.	160	0.20	0.032
May, June	55	0.39	0.022
July, Aug.*, Sep.	> 221	∿ 0.10	> 0.022
Oct., Nov., Dec.	115	0.19	0.022
1973	> 551	$\bar{x}$ ∿ 0.18	Σ > 0.098

$$\bar{X} = \frac{\Sigma\ mCi/km^2 \cdot 10^3}{\Sigma\ mm}\ pCi/l$$

*The bottles were run over in July and September



• Fig. 3.2.4.1. Quarterly ^{90}Sr levels in precipitation, 1959-73

Table 3.2.4.2

Strontium-90 in rain water collected in ion-exchange column collectors at Risø in 1973 (sampling area 0.325 m^2)

Month	mm	pCi $^{90}Sr/l$	mCi $^{90}Sr/km^2$
Jan. - Mar.	90	0.36	0.032
Apr. - June	87	0.46	0.040
July - Sep.	174	0.32	0.056
Oct. - Dec.	94	0.21	0.020
1973	Σ 445	$\bar{x}$ 0.33	Σ 0.148

3.2.5. Milk from a farm near Risø

Table 3.2.5 shows the radiostrontium and ^{137}Cs contents in milk collected in 1973 from a farm near Risø. The mean level was 2,3 S.U. as compared with 3,9 S.U. in 1972. Fig. 3.2.5 shows the ^{90}Sr levels in

"Risø" milk since 1959. The caesium-137 mean level was 2.9 pCi/l against 5.2 pCi/l in 1972.

Table 3.2.5

Strontium-90 and Caesium-137 in milk from Risø* in 1973

Month	pCi ^{90}Sr/g Ca	pCi ^{137}Cs/g K	pCi ^{137}Cs/l
Jan. - Mar.	2.59	1.68	2.66
Apr. - June	2.44	1.48	2.44
July - Sep.	1.96	2.58	4.09
Oct. - Dec.	2.28	1.49	2.51
1973	2.32	1.81	2.92

*The milk was collected from the milk-producing farm nearest to Risø

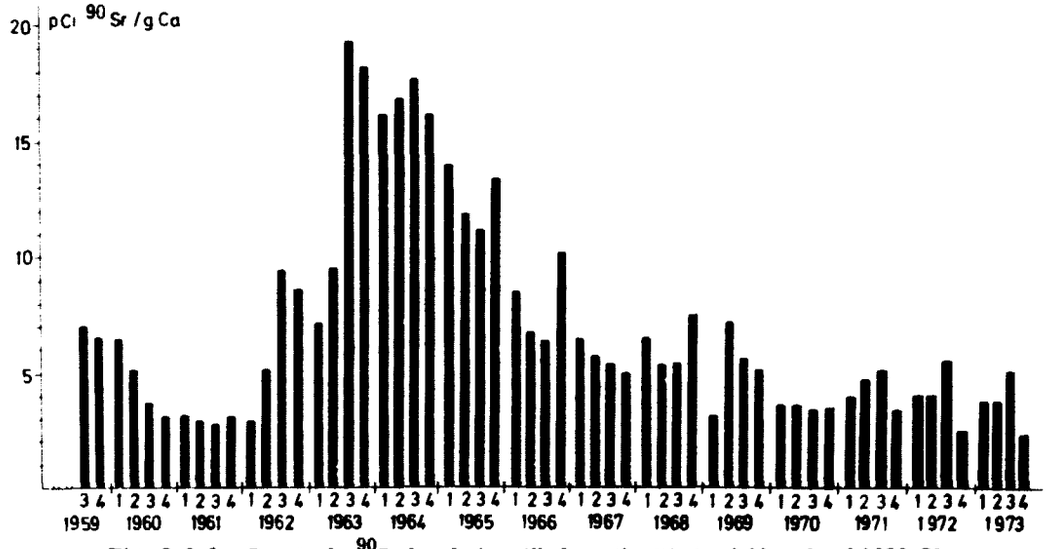


Fig. 3.2.5. Quarterly ^{90}Sr levels in milk from the Risø neighbourhood 1959-73

3.3. γ-Spectroscopy of Air Samples.

As in 1962-1972, half-weekly samples of air were collected by means of the air sampler described in Risø Report No. 23[1]. The half-weekly filters were measured on a 30 cm^3 Ge(Li) detector[8]. Table 3.3.1 shows the monthly means of the ^{137}Cs determinations. The peak value was observed in June (cf. also ^{90}Sr in air, table 3.2.1). The mean level in 1973 was 34% of the 1972 mean. The ^{137}Cs/^{90}Sr ratio in air filters was 1.2 in 1973 as compared with 1.7 in 1972.

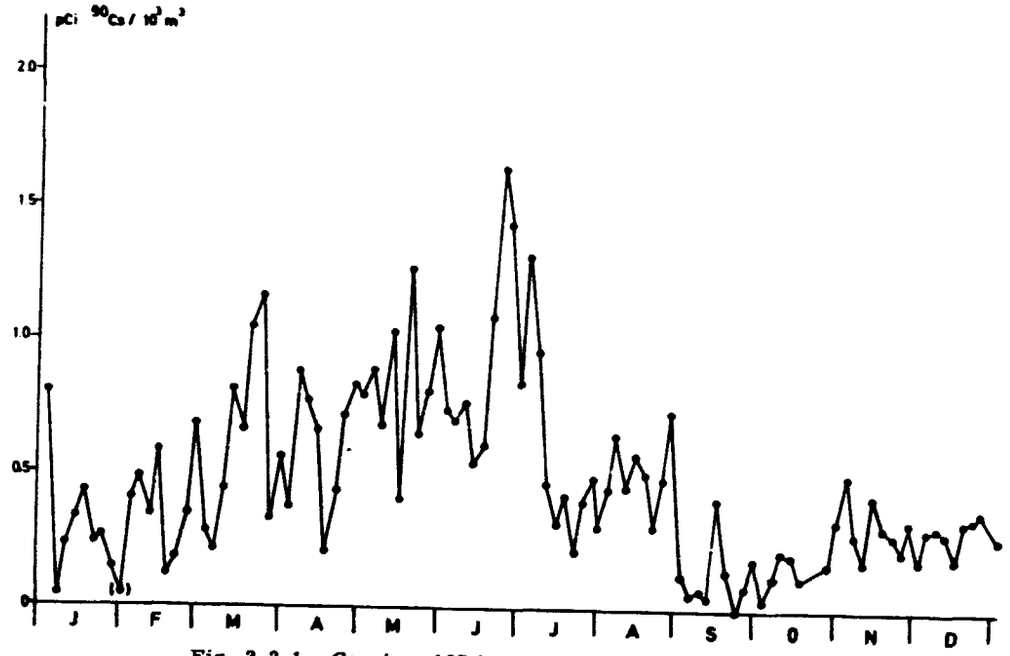


Fig. 3.3.1. Caesium-137 in ground level air at Risø in 1973

Table 3.3.1

Caesium-137 in glass-fibre air filters collected twice a week at Risø in 1973

Month	pCi ^{137}Cs/10^{3}m^3
Jan.	0.27±0.08
Feb.	0.39±0.07
Mar.	0.62±0.13
Apr.	0.60±0.08
May	0.84±0.09
June	0.93±0.13
July	0.58±0.13
Aug.	0.50±0.05
Sep.	0.13±0.04
Oct.	0.14±0.04
Nov.	0.32±0.04
Dec.	0.30±0.02
1973	0.47

The error term is the S.E. of the mean of the activity found in 8 or 9 filters collected during a month.

3.4. Y-spectroscopy of bedsoil samples from Roskilde Fjord

North of the outlet from the Waste Treatment Station (fig. 3.1.2.1) bedsoil samples have been collected with a van Veen sampler since 1972. Aliqvots of approx. 2 kg were analysed by Ge(Y) spectrometry. Tables 3.4.1 and 3.4.2 show the results. As the sample depth is not well defined for the van Veen sampler, we analysed a sample collected with a "HAPS" bottom corer[18] for comparison. From table 3.4.3 it appears that the van Veen collects samples down to an average depth of approx. 4 cm. The accumulated amount of ^{137}Cs down to 21 cm was 26 mCi/km^2, i.e. 1/3 of the corresponding soil level (cf. table 4.2.5).

Table 3.4.1

Caesium-137 in bed soil collected in Roskilde Fjord in 1973. (Van Veen sampler)

	^{137}Cs pCi/kg
2/5	305
30/5	433
28/6	388
26/11	267
Mean ±1 SE	348±38

Table 3.4.2

Caesium-137 in bed soil collected in Roskilde Fjord in 1972. (Van Veen sampler)

	^{137}Cs pCi/kg
29/3	459
10/5	273
20/7	367
12/8	374
9/9	412
4/12	352
Mean ±1 SE	373±25

Table 3.4.3

Caesium-137 in bed soil collected in Roskilde Fjord in October 1973. (HAPS sampler)

	^{137}Cs pCi/kg	^{137}Cs mCi/km^2
0-1 cm	503	4.6
1-2 cm	450	4.6
2-4 cm	280	5.8
4-8 cm	145	6.4
8-21 cm	29	4.6
Weighted mean	107	Σ 26.0

4. RADIOSTRONTIUM AND RADIOCAESIUM IN PRECIPITATION, SOIL, AND GROUND WATER IN DENMARK IN 1973

4.1. Strontium-90 in Precipitation

Samples of rain water were collected in 1973 from the ten State experimental farms (cf. fig. 4.1.1) in accordance with the principles laid down in Risø Report No. 63, p. 51[1].

Table 4.1.1 shows the results of the ^{90}Sr determinations and tables 4.1.2 and 4.1.3 the analysis of variance of the results. The variation with time was highly significant (P > 99.95%). The maximum fall-out occurred in May-June, when the mean content in precipitation was 0.74 pCi ^{90}Sr/l (cf. also the air measurements in 3.2.1) and the mean fall-out rate was 0.042 mCi $^{90}Sr/km^2$. Tables 4.1.2 and 4.1.3 show that the variation between locations was not significant. The 1973 mean levels for ten State experimental farms were 0.19 mCi $^{90}Sr/km^2$ and 0.31 pCi ^{90}Sr/l. In Appendix A the country mean level (area-weighted) is estimated to be 0.20 mCi $^{90}Sr/km^2$ for a mean precipitation amount of 630 mm (area-weighted), i.e. 43% of the fall-out rate in 1972.

A comparison between the amounts of precipitation found in the rain gauges used by the Danish Meteorological Institute[9] and the amounts collected in our rain bottles at the same locations showed in 1973 a mean ratio of 1.07 ± 0.04 (1 SE) between the two sampling systems.

Table 4.1.2

Analysis of variance of ln pCi ^{90}Sr/l precipitation in 1973 (from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	0.872	10	0.0872	0.70	-
Betw. months	16.384	5	3.2769	26.14	>99.95%
Remainder	5.892	47	0.1254		

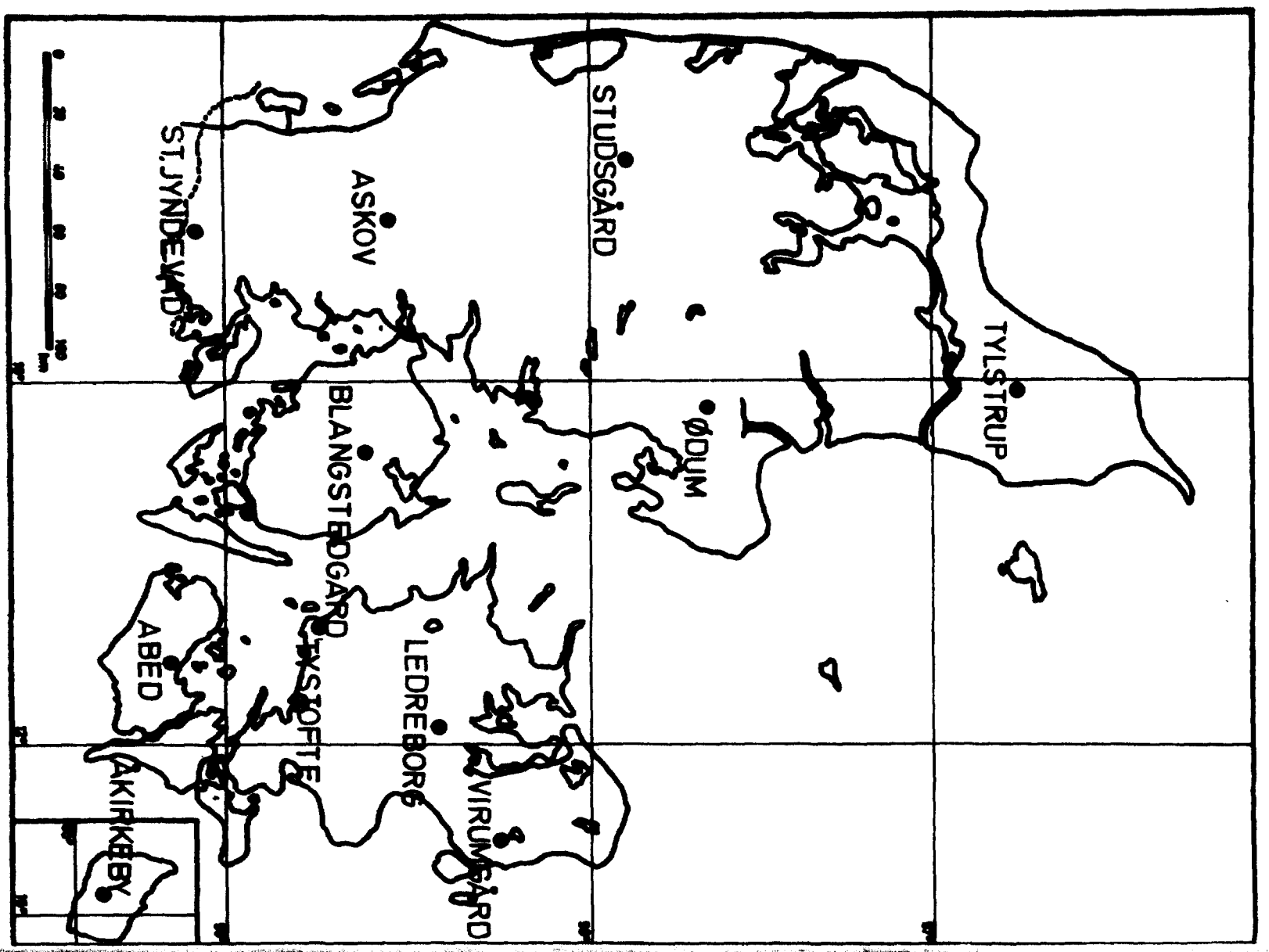


Fig. 4.1.1. State experimental farms in Denmark.

Table 4.1.1

Strontium-90 fall-out in Denmark in 1973

Period	Unit	Tylstrup	Studs-gård	Ødum	Askov	St. Jyn-devad	Blang-stedgård	Tystofte	Virum-gård	Abed	Åkirke-by	Ledreborg	Mean*
Jan.-Feb.	pCi/l	0.29	0.32	0.42	0.36	0.41	0.32	0.29	0.32	0.31	0.34	0.29	0.34
	mCi/km^2	0.028	0.036	0.028	0.035	0.033	0.025	0.022	0.027	0.022	0.035	0.019	0.029
Mar.-Apr.	pCi/l	(0.39)	0.39	0.53	0.42	0.40	0.28	0.41	0.38	0.47	0.55	0.40	0.42
	mCi/km^2	(0.047)	0.045	0.037	0.051	0.057	0.026	0.031	0.054	0.045	0.057	0.031	0.045
May-June	pCi/l	0.71	0.86	0.62	0.63	0.71	0.45	0.87	0.59	0.80	1.19	0.56	0.74
	mCi/km^2	0.046	0.056	0.042	0.060	0.066	0.022	0.032	0.025	0.027	0.043	0.034	0.042
July-Aug.	pCi/l	0.35	0.49	0.38	0.22	0.27	0.12 A	0.54	0.32	0.34	0.22	(0.32)	0.32
	mCi/km^2	0.042	0.039	0.040	0.025	0.051	0.009 A	0.037	0.057	0.023	0.009	(0.020)	0.033
Sep.-Oct.	pCi/l	0.13	0.15	0.17	0.12	0.11 A	0.25	0.22	0.36	0.13	0.13	0.55$^{\nabla}$	0.18
	mCi/km^2	0.013	0.018	0.016	0.015	0.018 A	0.027	0.019	0.044	0.015	0.013	0.014	0.020
Nov.-Dec.	pCi/l	0.18	0.07	0.12	0.21 A	0.18	0.14 B	0.27	0.15 A	0.18 B	(0.16)	0.10	0.17
	mCi/km^2	0.027	0.019	0.017	0.036 A	0.032	0.018 B	0.018	0.022 A	0.020 B	(0.018)	0.013	0.023
1973	pCi/l $\bar{x}$	0.31	0.28	0.33	0.31	0.30	0.24	0.39	0.32	0.31	0.35	0.31	0.31
	mCi/km^2 Σ	0.203	0.213	0.180	0.222	0.257	0.127	0.159	0.229	0.152	0.175	0.131	0.19
mm precipitation Σ		653	763	546	723	847	532	411	715	495	496	422	618

*Ledreborg not included in mean.

$^{\nabla}$Only October.

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

Figures in brackets calculated from VAR3[12].

Table 4.1.3

Analysis of variance of ln mCi $^{90}Sr/km^2$ precipitation in 1973 (from table 4.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	2.937	10	0.2937	2.39	>97.5%
Betw. months	5.876	5	1.1752	9.56	>99.95%
Remainder	5.779	47	0.1230		

4.2. Strontium-90 and Caesium-137 in Soil

As in previous years, soil was collected with a view to estimating the accumulated fall-out. As previously, the samples were collected in September from uncultivated areas all over the country (cf. fig. 4.1.1), down to a depth of 30 cm. Three sample was also collected from 30 to 50 cm's depth.

Beside samples from uncultivated soils, similar samples were collected from neighbouring cultivated soils to give a comparison between levels in the two sets of samples.

Tables 4.2.1 - 4.2.3 show the ^{90}Sr results. The mean values of the State experimental farms were 51 mCi $^{90}Sr/km^2$ in uncultivated soils and 47 mCi $^{90}Sr/km^2$ in cultivated soils. The mean ratios between uncultivated and cultivated soils were 1.10 ± 0.09 (1 SE) for mCi $^{90}Sr/km^2$ and 1.35 ± 0.24 for pCi $^{90}Sr/kg$. The location at Abed showed the most evident difference between the two sets of samples which might be due to the fact that the two

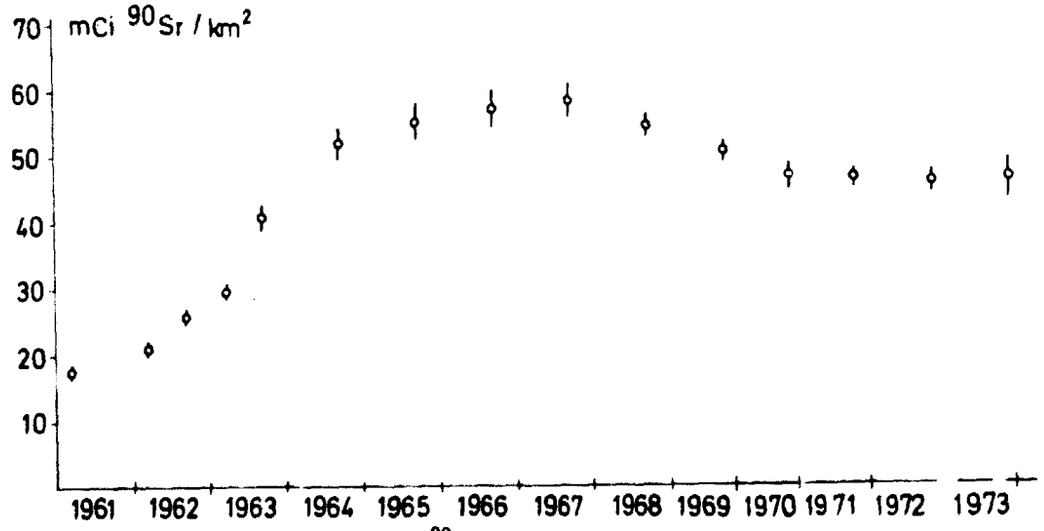


Fig. 4.2. Accumulated ^{90}Sr in Danish soil, collected at the State experimental farms 1961-73 (0 - 20 cm) (1 S. E. indicated)

locations differed much in soil density. The density of the uncultivated area was only half that of the cultivated location.

The 1973 levels were nearly equal to the 1972 figure: 52 mCi $^{90}Sr/km^2$.

From precipitation data[1,17], the accumulated fall-out in Denmark in 1973 was calculated to be 52 mCi/km^2, i.e. nearly equal to the level found in table 4.2.1.

Table 4.2.1

Strontium-90 in soil collected at the state experimental farms in September 1973 (0-30 cm)

		Tylstrup	Studs-gård	Ødum	Askov	St. Jyn-devad	Blang-stedgård	Tystofte	Abed	Åkirkeby	Mean	SD	SE
ulti-ted	mCi $^{90}Sr/km^2$	56±8	66±6	41±3	54	56±4	47±2	40±0	51±6	48±1	51	8	3
	pCi $^{90}Sr/kg$	133±18	190±19	110±8	131	111±10	130±5	79±2	242±28	134±1	140	48	16
lti-ted	mCi $^{90}Sr/km^2$	71±4	54±6	47±0	48±0	43±1	55±1	34±0	30±8	44±2	47	12	4
	pCi $^{90}Sr/kg$	151±8	122±12	112±1	114±1	98±2	132±2	87±1	70±18	92±4	109	25	8

Table 4.2.2

Strontium-90 in soil collected from the surroundings of Roskilde in September 1973 (0-30 cm)

		Bolund	Ledreborg (Roskilde Fælled)	Skydebanen	Mean	SD	SE
Uncultivated	mCi $^{90}Sr/km^2$	42±2	49±0	54±2	48	6	3
	pCi $^{90}Sr/kg$	190±12	120±0	178±6	163	37	22
Cultivated	mCi $^{90}Sr/km^2$		55±0		55		
	pCi $^{90}Sr/kg$		118±1		118		

From Ødum, Jyndevad, and Abed we also took samples between 30 and 50 cm, (cf. table 4.2.3). It is surprising that on average we found more than 9 mCi $^{90}Sr/km^2$ at these depths although our precipitation data through

Table 4.2.3

Strontium-90 in soil collected at three state experimental farms in September 1973 (30-50 cm)

		Ødum	Jyndevad	Abed	Mean	SD	SE
Uncultivated	mCi $^{90}Sr/km^2$	2.4±0.5	17±0	8.8±0.4	9.4	7.3	4.2
	pCi $^{90}Sr/kg$	6.4±1.2	37±0	27 ±1	23	16	9
Cultivated	mCi $^{90}Sr/km^2$	9.6±1.4	25±1	7.8±1.4	14	19	5
	pCi $^{90}Sr/kg$	25 ±3	52±2	23 ±3	33	16	9

the years[1] indicate that we should have accounted for nearly all deposited ^{90}Sr in the upper 30 cm of the soil column. As mentioned already in the 1972 report[1], the discrepancy might be due to contamination from surface soil during the sampling of the deeper layers of the soil.

The determination of ^{137}Cs is shown in tables 4.2.4 - 4.2.6. The

Table 4.2.4

Caesium-137 in soil collected at the state experimental farms in September 1973
(0-30 cm)

		Tylstrup	Studs-gaard	Ødum	Askov	St. Jyn-devad	Blang-stedgård	Tystofte	Abed	Akirkeby	Mean	SD	SE
Uncultivated	mCi $^{137}Cs/km^2$	99	110	86	108	131	96	70	94	90	97	18	6
	pCi $^{137}Cs/kg$	232	316	230	261	257	238	138	446	247	263	84	28
	g K/kg	13.9	6.8	16.1	15.0	7.8	16.6	18.4	12.6	19.4	14.0	4.4	1.5
Cultivated	mCi $^{137}Cs/km^2$	125	114	80	120	97	96	77	73	95	97	19	6
	pCi $^{137}Cs/kg$	265	256	191	285	220	232	190	174	202	224	38	13
	g K/kg	14.7	6.9	10.6	13.6	7.2	10.3	16.6	10.8	21.2	15.1	5.1	1.7

Table 4.2.5

Caesium-137 in soil collected from the surroundings of Roskilde in September 1973
(0-30 cm)

		Bolund	Ledreborg (Roskilde Fælled)	Skydebanen	Mean	SD	SE
Uncultivated	mCi $^{137}Cs/km^2$	77	80	86	81	5	3
	pCi $^{137}Cs/kg$	350	197	285	277	77	44
	g K/kg	17.1	19.7	19.7	18.8	1.5	0.9
Cultivated	mCi $^{137}Cs/km^2$	-	89	-	89	-	-
	pCi $^{137}Cs/kg$	-	191	-	191	-	-
	g K/kg	-	18.8	-	18.8	-	-

Table 4.2.6

Caesium-137 in soil collected at three state experimental farms
in September 1973
(30-50 cm)

		Ødum	Jyndevad	Abed	Mean	SD	SE
Uncultivated	mCi $^{137}Cs/km^2$	5.9 A	7.4 A	14	9.1	4.3	2.5
	pCi $^{137}Cs/kg$	16 A	16 A	42	25	15	9
	g K/kg	14.9	8.0	15.8	12.9	4.3	2.5
Cultivated	mCi $^{137}Cs/km^2$	7.4 B	23	8.2	12.9	8.8	5.1
	pCi $^{137}Cs/kg$	19 B	48	23	30	16	9
	g K/kg	20.1	8.4	18.3	15.6	6.3	3.6

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

main ratios between uncultivated and cultivated soils were 1.00 ± 0.06 (1 SE) for mCi $^{137}Cs/km^2$ and 1.20 ± 0.16 for pCi $^{137}Cs/kg$. Considering the samples collected from 30 to 50 cm (table 4.2.6), we may still notice significant levels, also of ^{137}Cs.

Table 4.2.7

The ratio $^{137}Cs/^{90}Sr$ in soil (0-30 cm) from the state experimental farms, 1973
(from tables 4.2.1 and 4.2.4)

	Tylstrup	Studs-gård	Ødum	Askov	St. Jyn-devad	Blang-stedgård	Tystofte	Abed	Akirkeby	Mean	SD	SE
Uncultivated	1.77	1.67	2.13	2.30	2.34	1.83	1.75	1.34	1.86	1.91	0.31	0.07
Cultivated	1.76	2.11	1.67	2.50	2.26	1.75	2.26	2.43	2.20	2.10	0.31	0.10

Tables 4.2.7 - 4.2.9 finally show the $^{137}Cs/^{90}Sr$ ratios in the samples. As previously[1] we find the $^{137}Cs/^{90}Sr$ higher than the ratio expected from fall-out. In a recent Japanese publication[19] the authors found for 15 different soil types a mean $^{137}Cs/^{90}Sr$ ratio of 2.2 ± 0.1 (1 SE) which is also higher than the theoretical ratio of 1.6 - 1.7. However, there were no comments upon this discrepancy.

As we believe in our estimate of accumulated ^{90}Sr fall-out, because our precipitation data and soil data are in close agreement through the years, and furthermore we have just as much confidence in our Ge(Y) spectroscopical analysis of soil, we are forced to conclude that a sampling error of the type mentioned above causes the higher $^{137}Cs/^{90}Sr$ ratios.

Table 4.2.8

The ratio $^{137}Cs/^{90}Sr$ in soil (0-30 cm) collected from the surroundings of Roskilde, 1973
(from tables 4.2.2 and 4.2.5)

	Bolund	Ledreborg (Roskilde Fælled)	Skydebanen	Mean	SD	SE
Uncultivated	1.83	1.63	1.59	1.68	0.13	0.07
Cultivated		1.62		1.62		

Table 4.2.9

The ratio $^{137}Cs/^{90}Sr$ in soil (30-50 cm) from three state experimental farms, 1973
(from tables 4.2.3 and 4.2.6)

	Ødum	Jyndevad	Abed	Mean	S.D.	S.E.
Uncultivated	2.46	0.44	1.59	1.50	1.01	0.58
Cultivated	0.77	0.92	1.05	0.91	0.14	0.08

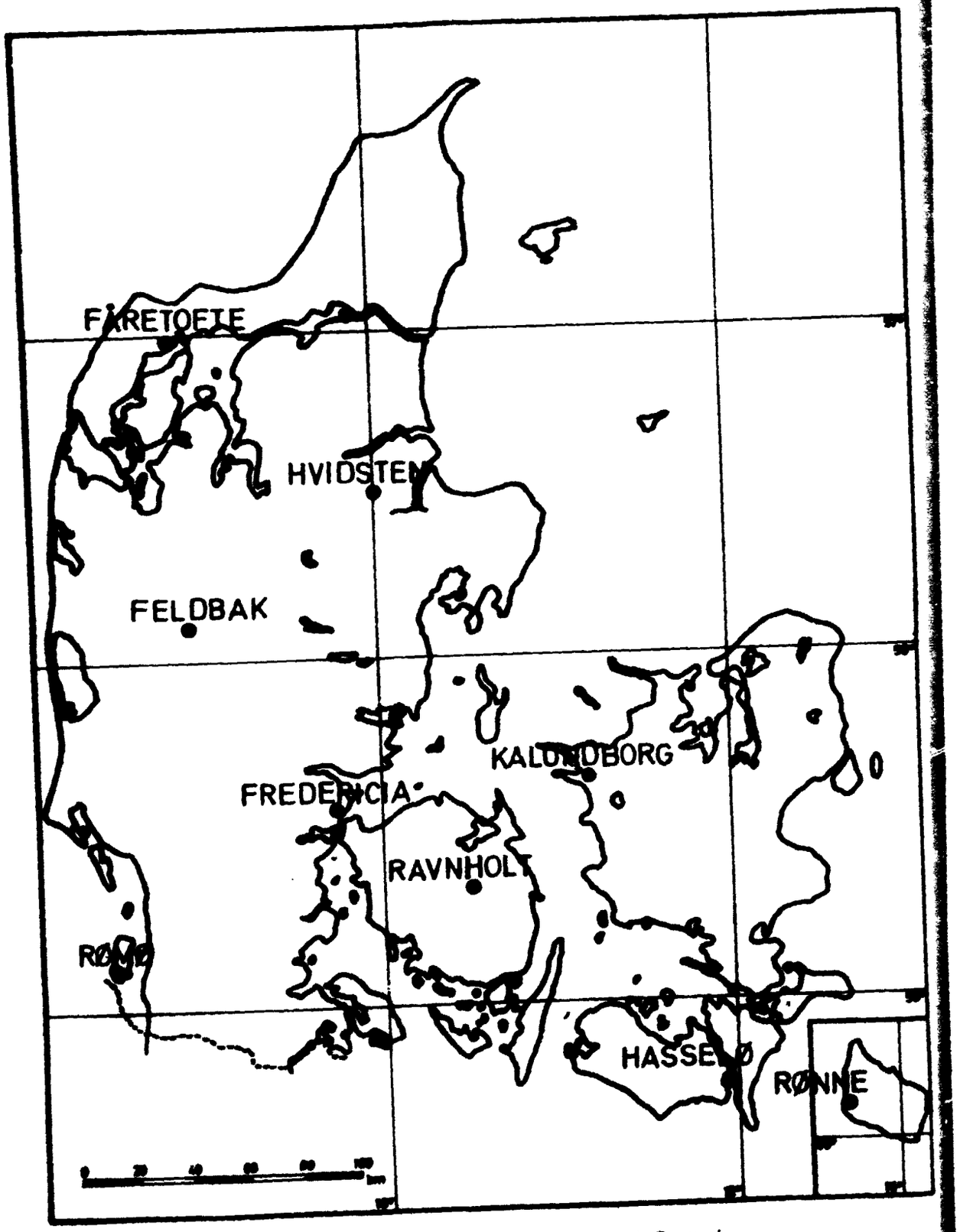


Fig. 4.3.1. Ground-water sampling locations in Denmark.

4.3. Strontium-90 in Ground Water

As in previous years, ground water was collected in March from the nine locations selected by L. J. Andersen, M. Sc., Geological Survey of Denmark, in 1961.

Fig. 4.3.1 shows the sample locations and table 4.3.1 the results of the ^{90}Sr analyses (cf. also 5.8.4).

The median level of ^{90}Sr in 1973 was approx. half the level found in 1972. Fig. 4.3.2 shows the median levels in Danish ground water since 1961.

Table 4.3.1

Strontium-90 in ground water collected in March 1973

	^{90}Sr pCi/l	g Ca/l	mg Sr/g Ca
Hvidsten	0.001 B	0.058	2.28
Feldbak	1.18	0.024	1.30
Rømø	0.022	0.028	2.95
Rønne	0.021 A	0.023	2.15
Hasselø	0.001 B	0.161	1.75
Fåretofte	0.003 A	0.129	1.00
Kalundborg	0.004	0.081	3.90
Ravnholt	0.006 A	0.127	0.80
Fredericia	0.020 B	0.055	2.55
Mean	0.140	0.076	2.08
Median	0.006	0.058	2.15

A: relative S.D.: 20-33%

B: relative S.D.: > 33%

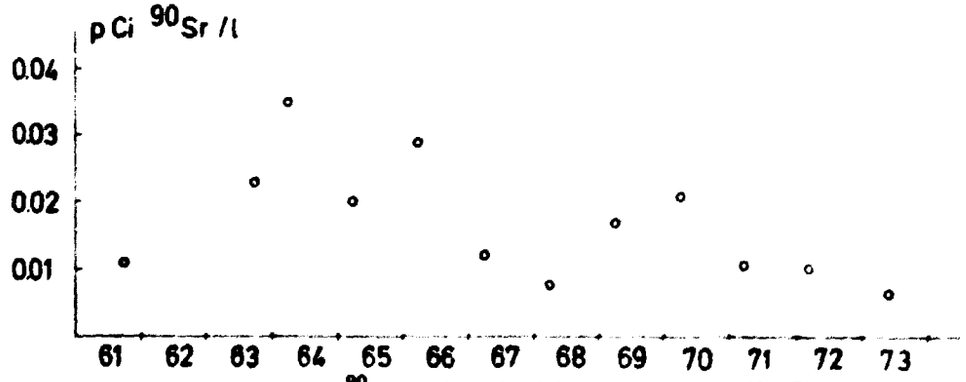


Fig. 4.3.2. Median ^{90}Sr levels in Danish ground water, 1961-73

As shown in fig. 4.3.3 the ^{90}Sr levels in ground water from Feldbak have shown a marked increase through the years.

The filtering layer at Feldbak consists of 4-6 m sand, and we may thus expect a rather low ion exchange capacity compared with the majority of other Danish ground water locations, where the depth of strontium in soil is about 20 m or more and where the filtering materials normally contain clay (cf. Risø Report No. 41, table 5.5)[1].

Caesium-137 was not detectable in the Feldbak samples.

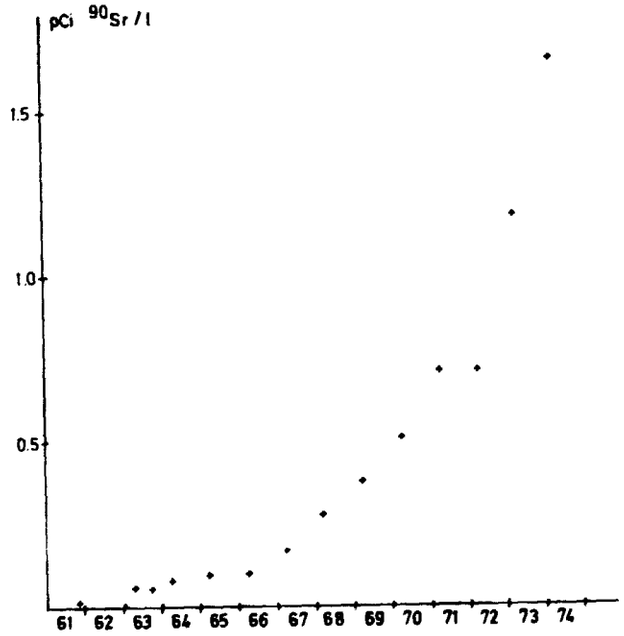


Fig. 4.3.3. Strontium-90 in ground water collected at Feldbak 1961-74

4.4. Strontium-90 in Fresh Water from Danish Streams and Lakes

In March 1973 we repeated the sampling of fresh water from Danish streams and lakes first carried out in 1971 (Risø Report No. 265)[1].

Comparing the mean levels for the two years, we notice that the 1973 levels were a little lower. The streams contained 0.37 pCi $^{90}Sr/l$ in 1971 and 0.31 pCi/l in 1973. The mean levels in the lakes were 1.50 pCi $^{90}Sr/l$ and 1.29 pCi $^{90}Sr/l$ respectively. However, the difference between the levels from the two years was not significant. As the fallout-rate has decreased markedly since 1971, we may conclude that the fresh water levels in streams and lakes at present do not depend strongly upon the

actual fallout-rates, but rather on the accumulated levels in the soil. An implication of this is that the ^{90}Sr contents of fresh-water fish will decrease rather slowly, just as was observed for salt-water fish.

Caesium-137 was not detectable in the fresh-water samples.

Table 4.4

Strontium-90 and Caesium-137 in Danish streams and lakes. March 1973

Stream or lake	Country part	pCi $^{90}Sr/l$	g Ca/l	mg Sr/g Ca	Symbol on map (fig. 4.4)
Bangsbo å (stream)	N-Jutland	0.35	0.056	1.6	1 å
Nors sø (lake)	N-Jutland	2.70	0.034	2.4	1 s
Gudenå (stream)	E-Jutland	0.26 A	0.054	2.8	2 å
Mossø (lake)	E-Jutland	0.44	0.073	2.9	2 s
Skjern å (stream)	W-Jutland	0.25	0.027	1.2	3 å
Flynder sø (lake)	W-Jutland	0.23	0.043	3.3	3 s
Ribe å (stream)	S-Jutland	0.21	0.038	5.7	4 å
Hostrup sø (lake)	S-Jutland	1.92	0.026	0.4	4 s
Odense å (stream)	Funen	0.32	0.100	2.1	5 å
Arreskov sø (lake)	Funen	1.44	0.062	6.5	5 s
Suså (stream)	Zealand	0.28	0.058	6.9	6 å
Arresø (lake)	Zealand	1.24	0.059	4.2	6 s
Halsted å (stream)	Lolland-Falster	0.25	0.161	4.1	7 å
Søndersø (lake)	Lolland-Falster	1.47	0.093	2.1	7 s
Læs å (stream)	Bornholm	0.55	0.074	2.2	8 å
Alm. Gråmyre sø (lake)	Bornholm	0.91 A	0.044	0.7	8 s_{11}
Stream mean ±1 S.E.		0.31±0.04	0.071±0.015	3.3±0.7	
Lake mean ±1 S.E.		1.29±0.28	0.054±0.008	2.8±0.7	

A: relative S.D.: 20-33%

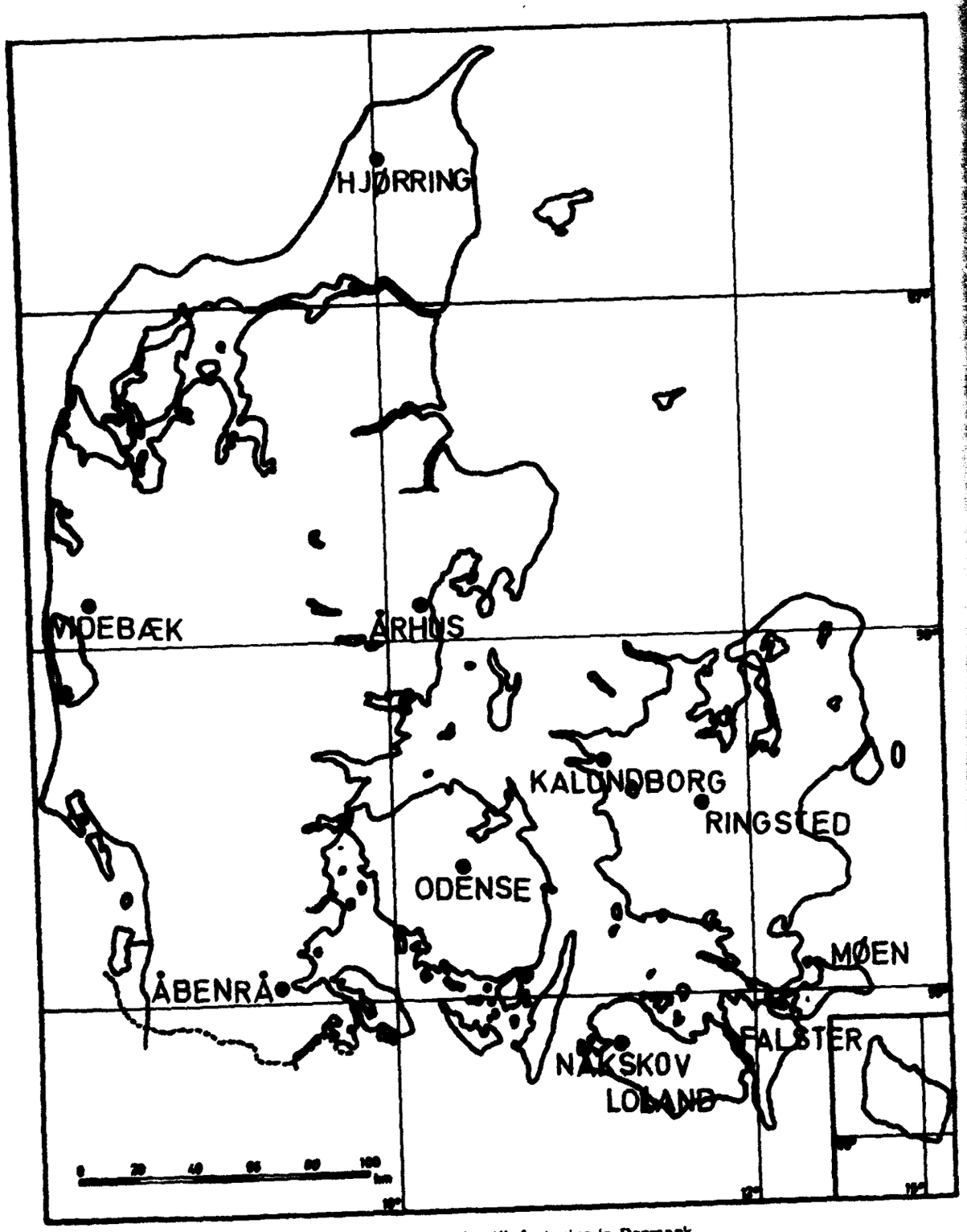


Fig. 5.1.1. Dried-milk factories in Denmark.

5. RADIOSTRONTIUM AND RADIOCAESIUM IN DANISH FOOD IN 1973

5.1. Strontium-90 and Caesium-137 in Dried Milk from the Entire Country

As in the previous years, monthly samples of dried milk were collected from seven locations in Denmark (cf. fig. 5.1.1) and analysed for ^{90}Sr and ^{137}Cs.

Table 5.1.1 shows the results of the ^{90}Sr determinations and table 5.1.2 the analysis of variance of the results. As in 1972 but contrary to previous years the variation between months was significant for S.U.; the levels in January-May was 27% higher than in June-December. The S.U. mean level in 1973 was 4.7 pCi ^{90}Sr/g Ca or approx. 70% of the 1972 mean.

As previously, the milk from eastern Denmark shows significantly lower levels than that from Jutland.

Table 5.1.1

Strontium-90 (pCi/g Ca) in Danish dried milk in 1973

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	7.1	4.9	6.5	6.8	4.6	3.6	3.5	5.3
Feb.	8.1	5.2	7.5	7.3	4.2	3.1	3.8	5.6
Mar.	6.2	4.4	8.2	5.4	6.2	3.7	3.4	5.4
Apr.	6.0	6.3	6.0	7.7	3.5 A	3.9	3.6	5.3
May	6.2	5.4	4.9	6.1	7.4 A	3.7	2.9	5.2
June	4.9	4.5	6.3	5.2	3.5	3.3	2.9	4.4
July	5.1	4.9	5.8	5.1	3.4	3.7	3.0	4.4
Aug.	5.0	5.0	5.2	6.1	2.9	2.8	2.4	4.2
Sep.	4.8	4.8	5.4	5.5	2.8	2.5 B	2.3	4.0
Oct.	4.8	5.3	4.4	5.0	3.2	2.4	2.8	4.0
Nov.	5.5	5.2	5.5	4.5	3.1	3.0	2.7	4.2
Dec.	4.6	4.7	6.7	(5.3)	3.5	3.1	2.2	4.3
Mean	5.7	5.0	6.0	5.8	4.0	3.2	3.0	4.7

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

Figures in brackets calculated from VAR3[12].

As 1 litre of milk contains 1.2 g Ca, the mean ^{90}Sr content in Danish milk produced in 1973 was 5.6 pCi/l.

Table 5.1.2

Analysis of variance of ln pCi ^{90}Sr/g Ca in dried milk in 1973
(from table 5.1.1)

Variation	SSD	f	s^2	v^2	P
Betw. locations	6.389	6	1.0649	47.47	>99.95%
Betw. months	1.323	11	0.1202	5.36	>99.95%
Remainder	1.458	65	0.0224		

Table 5.1.3 shows the results of the ^{137}Cs determinations and table 5.1.4 the analysis of variance of the results. Contrary to previous years, the variation between months was not significant. The M.U. mean level in 1973 was 3.6 pCi ^{137}Cs/g K or 55% of the 1972 level.

Figs. 5.1.2 and 5.1.3 show the quarterly S.U. and M.U. values since October-December 1959 (cf. also Appendix C).

Table 5.1.3.

Caesium-137 (pCi/g K) in Danish dried milk in 1973

Month	Hjørring	Århus	Videbæk	Åbenrå	Odense	Ringsted	Lolland-Falster Møn	Mean
Jan.	4.6	4.0	6.2	6.5	3.2	1.6	3.0	4.2
Feb.	3.5	3.1	4.0	5.5	1.5	1.8	2.6	3.1
Mar.	3.1	3.1	6.4	4.3	3.3	1.9 A	2.3 A	3.5
Apr.	5.0	3.3	5.7	5.8	0.8 B	2.1	4.0	3.8
May	2.3	3.2	4.4	4.6	1.8 A	4.1	2.1	3.2
June	3.3 A	3.2	5.8	4.8	1.6 B	2.5 A	2.3	3.4
July	7.7	4.1	8.0	5.8	2.2 A	2.8	2.4	4.7
Aug.	4.7	6.5	4.9	5.5	3.6	2.7	1.7	4.2
Sep.	5.3	5.9	4.9	5.3	1.5 A	2.0 A	1.0 B	3.7
Oct.	3.6	3.2	4.6	4.4	2.0 B	1.6 B	1.3 B	3.0
Nov.	4.2	3.9	3.8	2.6 A	1.5 A	1.6 A	2.2 A	2.8
Dec.	4.2	4.5	4.0	(4.5)	2.9 A	1.0 B	0.7 B	3.1
Mean	4.3	4.0	5.2	5.0	2.2	2.1	2.1	3.6

As 1 litre of milk contains approx. 1.66 g K, the mean ^{137}Cs content in Danish milk in 1973 was estimated at 6.0 pCi/l.

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

Figures in brackets calculated from VAR3[12].

Table 5.1.4

Analysis of variance of ln ^{137}Cs/g K in Danish dried milk 1973
(from table 5.1.3)

Variation	SSD	f	s^2	v^2	P
Betw. locations	13.466	6	2.2443	18.80	>99.95%
Betw. months	2.068	11	0.1880	1.57	-
Remainder	7.759	65	0.1194		

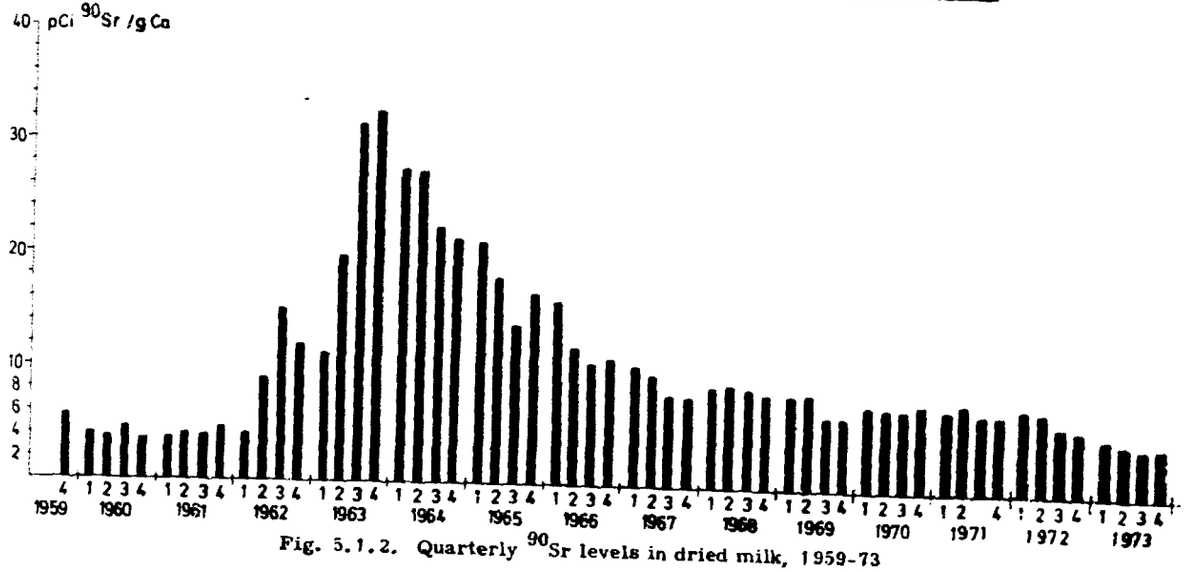


Fig. 5.1.2. Quarterly ^{90}Sr levels in dried milk, 1959-73

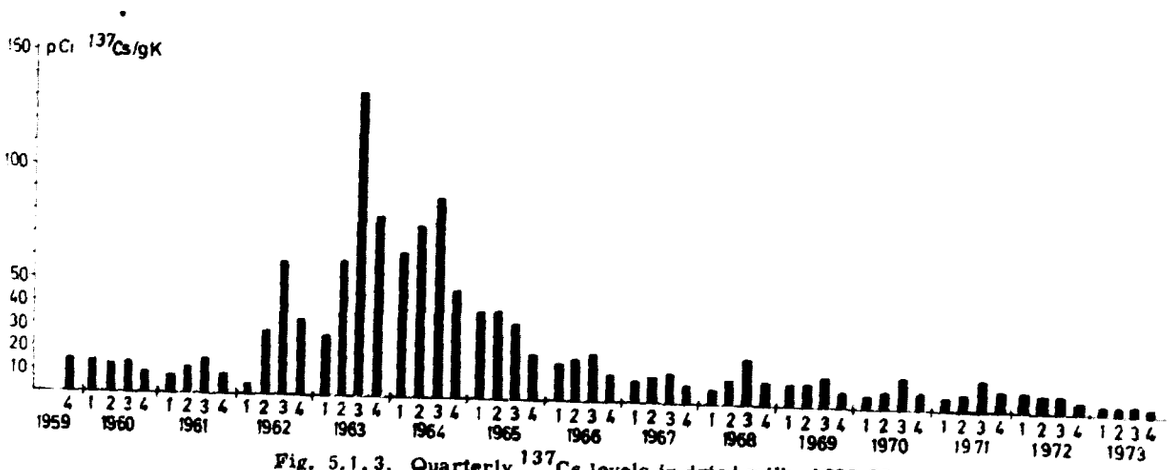


Fig. 5.1.3. Quarterly ^{137}Cs levels in dried milk, 1959-73

5.2. Strontium-90 and Caesium-137 in Fresh Milk from the Entire Country

The samples of fresh milk were collected in the eight zones and in Copenhagen (cf. fig. 5.2.1) in connection with the total-diet collection (cf. 5.7).

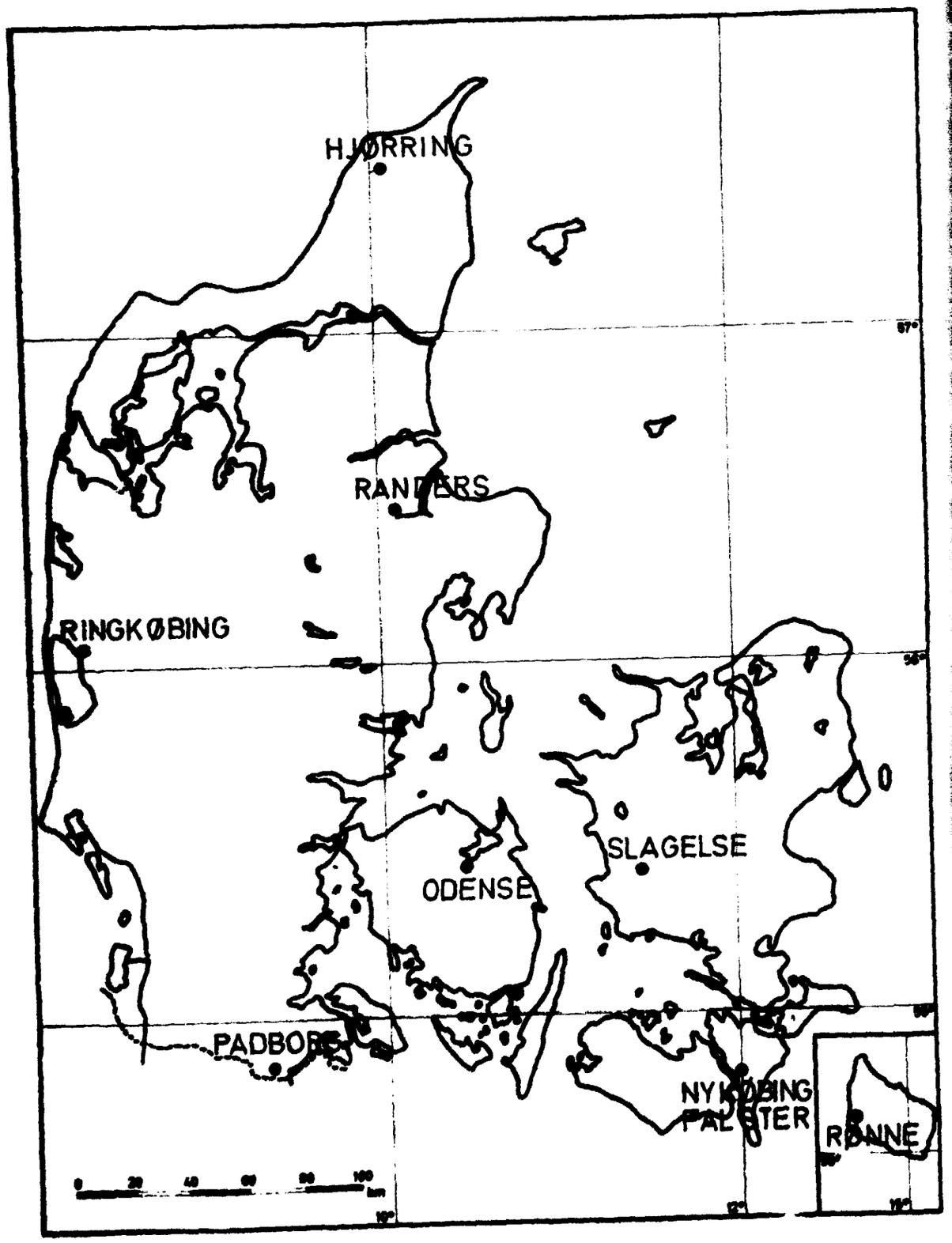


Fig. 5.2.1. Sample locations for fresh milk, bread and total diet in 1973

Table 5.2.1 shows the results of the determinations of radiostrontium and ^{137}Cs in consumer milk.

The production-weighted means for ^{90}Sr and ^{137}Cs in Danish consumer milk in 1973 collected in June and December were 5.2 S.U. (~ 6 pCi ^{90}Sr/l) and 2.4 M.U. or 4.0 pCi ^{137}Cs/l respectively.

We could contrary to previous years observe no systematic tendency for the fresh milk to show lower levels than the corresponding dried milk.

Table 5.2.1

Strontium-90 and Caesium-137 in fresh milk in 1973

Zone	June 1973			December 1973		
	pCi ^{90}Sr/g Ca	pCi ^{137}Cs/g K	pCi ^{137}Cs/l	pCi ^{90}Sr/g Ca	pCi ^{137}Cs/g K	pCi ^{137}Cs/l
I: N-Jutland	5.1	1.5 A	2.4 A	4.4	1.8 A	3.2 A
II: E-Jutland	4.5	3.5	5.3	4.6	4.3	7.4
III: W-Jutland	6.1	4.4	7.1	6.7	4.9	8.2
IV: S-Jutland	9.7	4.3	7.1	6.5	2.9 A	5.4 A
V: Funen	3.5	2.2	3.6	3.4	1.2 B	2.1 B
VI: Zealand	3.9 A	2.7 A	4.1 A	2.8	1.6 A	2.8 A
VII: Lolland-Falster	2.6	0	0	2.2	0.9 A	1.4 A
VIII: Bornholm	3.7	1.6 A	2.5 A	3.2	0	0
Mean	4.9	2.5	4.0	4.2	2.2	3.8
Copenhagen	3.7	3.6	6.0	3.2	0	0
Population-weighted mean	4.6	3.2	5.1	4.1	2.1	3.6
Production-weighted mean	5.4	3.1	5.0	4.9	3.2	5.5

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

5.3. Strontium-90 and Caesium-137 in Grain from the Entire Country

As in previous years, grain samples were obtained from ten State experimental farms (cf. fig. 4.1.1). Virumgård was replaced by Ledreborg in 1969. Strontium-90 was determined as previously (Risø Report No. 63[1]), and ^{137}Cs was measured on ashed samples by γ-spectrometry on a Ge-detector.

Table 5.3.1 shows the measurements of ^{90}Sr in grain in 1973. According to Appendix B, approx. 2/3 of all rye in Denmark is grown in Jutland and 1/3 in the eastern part of the country. As regards wheat, 4/5 is produced in eastern Denmark and 1/5 in Jutland. In the calculation of the means in tables 5.3.1 and 5.3.4 Jutland is represented by four rye figures and seven wheat figures, while eastern Denmark contributes nine wheat figures and four rye figures. Thus the means in tables 5.3.1 - 5.3.4 for

Table 5.3.1

Strontium-90 in Danish grain in 1973

	Rye		Barley		Wheat		Oats	
	pCi ^{90}Sr/kg	S.U.	pCi ^{90}Sr/kg	S.U.	pCi ^{90}Sr/kg	S.U.	pCi ^{90}Sr/kg	S.U.
Tylstrup	28±3	86±10	33±1	80±4	s: 20±0	s: 61±6	48±14	69±19
Studsgård	w: 46±2	w: 107±5	27±0	59±8	s: 42±2 w: 36±0	s: 99±2 w:105±6	60±2	67±12
Ødum	-	-	13	32	w: 12±1	w: 41±3	23±3	27±3
Askov	27±3	63±15	30±1	51±0	24±1	89±9	52±5	51±7
St. Jyndevad	w: 44±1	w: 86±5	34±2	83±9	s: 45±0 w: 42±1	s: 99±4 w:124±10	56±1	64±4
Blangstedgård	14±0	36±2	10±1	17±1	w: 6±1	w: 23±4	20±0	18±0
Tystofte	13±0	37±0	14±2	27±4	s: 7±1 w: 16±1	s: 31±5 w: 49±2	21±2	25±4
Ledreborg	25±1	59±4	13±0	26±0	s: 11±1 w: 11±2	s: 29±3 w: 43±9	19±1	23±1
Abed	-	-	11±1	21±0	s: 9±2 w: 4±0	s: 24±5 w: 15±0	17±1	17±0
Åkirkeby	12±1	27±1	13±1	26±1	s: 14±0 w: 12±0	s: 35±1 w: 56±2	39±2	48±2
Mean	26	63	20	42	19	58	36	41

w: winter variety, s: spring variety.

wheat are higher than the production-weighted means for the country while the rye means probably are too low. Table 5.3.2 gives the analysis of variance of the S.U. figures and table 5.3.3 that of the pCi ^{90}Sr/kg grain figures.

Table 5.3.2 shows that the variation in S.U. between species was significant. Rye showed the highest S.U. levels and oats the lowest. The pCi ^{90}Sr/kg figures also show a significant difference between species. (Oats > wheat).

Table 5.3.2

Analysis of variance of ln S.U. in grain in 1973
(from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	1.956	3	0.6521	6.14	>99.5%
Betw. locations	23.066	9	2.5629	24.14	>99.95%
Spec. x loc.	2.654	25	0.1062	2.66	>99.5%
Remainder	1.959	49	0.0400		

Table 5.3.3

Analysis of variance of ln pCi ^{90}Sr/kg grain in 1973
(from table 5.3.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	7.024	3	2.3414	18.95	>99.95%
Betw. locations	25.236	9	2.8040	22.69	>99.95%
Spec. x loc.	3.089	25	0.1236	3.61	>99.95%
Remainder	1.676	49	0.0342		

As in previous years, the variation with location was highly significant; the mean pCi ^{90}Sr/kg level for grain from Jutland was 2.5 times that in eastern Denmark.

Table 5.3.4 shows the measurements of ^{137}Cs in grain in 1973, table 5.3.5 the analysis of variance of the M.U. figures and table 5.3.6 the analysis of variance of the pCi ^{137}Cs/kg grain figures. The ^{137}Cs levels

Table 5.3.4

Caesium-137 in Danish grain in 1973

	Rye		Barley		Wheat		Oats	
	pCi ^{137}Cs/kg	M.U.	pCi ^{137}Cs/kg	M.U.	pCi ^{137}Cs/kg	M.U.	pCi ^{137}Cs/kg	M.U.
Tylstrup	18.8 A	4.1 A	10.9 B	2.3 B	s: 0	s: 0	4.0 B	0.9 B
Studsgård	w: 12.8 A	w: 2.3 A	0	0	s: 5.5 B w: 4.5 B	s: 1.3 B w: 0.9 B	6.4 B	1.2 B
Ødum	-	-	15.4 A	3.3 A	w: 11.0 B	w: 2.2 A	7.0 B	1.3 B
Askov	7.4 B	1.4 B	19.8	4.3	w: 5.3 B	w: 1.2 B	13.5 A	2.4 A
St. Jyndevad	31.2	5.5	12.0 B	2.2 B	s: 17.6 w: 7.0 B	s: 3.8 w: 1.8 B	27.9	5.7
Blangstedgård	14.6 A	2.8 A	0	0	w: 7.6 A	w: 2.0 A	12.6 A	2.6 A
Tystofte	4.7 B	1.0 B	0	0	s: 7.7 B w: 4.4 B	s: 1.8 B w: 1.0 B	21.1 A	3.7 A
Ledreborg	5.2 B	1.3 B	0	0	s: 6.5 B w: 11.0 B	s: 1.9 B w: 2.8 B	5.1 B	1.4 B
Abed	-	-	15.4	3.0	s: 6.6 B w: 10.6 A	s: 2.9 B w: 2.7 A	11.9 A	2.3 A
Åkirkeby	0	0	6.2 B	1.3 B	s: 14.0 A w: 0	s: 2.8 A w: 0	8.4 A	1.3 A
Mean	11.8	2.3	8.0	1.6	7.5	1.8	11.8	2.2

w: winter variety, s: spring variety

A: relative S.D.: 20-33%

B: relative S.D.: > 33%

Table 5.3.5

Analysis of variance of ln pCi ^{137}Cs/g K in grain in 1973
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	0.108	3	0.0361	0.14	-
Betw. locations	2.894	9	0.3216	1.28	-
Species x loc.	4.523	18	0.2513	1.86	-
Remainder	0.674	5	0.1348		

Table 5.3.6

Analysis of variance of ln pCi ^{137}Cs/kg in grain in 1973
(from table 5.3.4)

Variation	SSD	f	s^2	v^2	P
Betw. species	1.030	3	0.3434	1.10	-
Betw. locations	6.398	9	0.7108	2.28	-
Species x loc.	7.181	23	0.3122	0.37	-
Remainder	5.030	6	0.8384		

in grain from 1973 were very low due to the low fall-out rate in May-August. In fact, some samples showed negative ^{137}Cs contents; these results have been recorded as zero. Consequently the true average contents of ^{137}Cs in Danish grain may be a little lower than indicated in the table. Due to the low activity levels the analytical error was large, and we find no significance in any of the anovas.

If the S.U. levels in grain from the harvest of 1973 are compared with the levels from 1972[1], we find the 1973 figures to be 0.64 times the 1972 levels.

The ^{137}Cs content in grain from the 1973 harvest was on the average 0.4 times the 1972 means. The fall-out rate in May-August 1973 was 0.3 times that in May-August 1972. (The period May-August was selected because experiments have shown[10] that the contamination of grain with ^{137}Cs takes place in the period from before the emergence of the ears until harvest). This observation is in reasonable agreement with that of the previous years and fits the hypothesis that the ^{137}Cs level in grain depends mainly upon the fall-out rate.

In Appendix C is shown a comparison between observed and predicted ^{90}Sr and ^{137}Cs levels in 1973.

Table 5.3.7 shows the stable-strontium content in grain in relation to the calcium content, and table 5.3.8 is an analysis of variance of the figures. As previously[1], wheat contained more stable strontium per g Ca than the other species, and the stations in Jutland showed generally higher figures than the eastern locations.

Table 5.3.7

Stabile strontium in grain (mg Sr/g Ca) collected in 1973

	Rye	Barley	Wheat		Oats
	w	s	w	s	
Tylstrup	4.1	3.8		3.4	2.3
Studsgård	4.2	2.7	4.4	3.4	3.2
Ødum		3.4	4.5		2.6
Askov	2.3	2.1		3.5	2.5
St. Jyndevad	2.8	2.9	3.8	3.2	1.7
Blangstedgård	2.1	2.2	2.8		2.6
Tystofte	2.6	2.1	3.8	2.3	1.8
Ledreborg	3.8	1.6	3.2	1.8	1.8
Abed		0.6	1.4	2.8	2.1
Akirkeby	1.3	1.1	2.5	1.6	1.4

Table 5.3.8

Analysis of variance of ln mg Sr/g Ca in grain in 1973 (from table 5.3.7)

Variation	SSD	f	s^2	v^2	p
Betw. species	1.290	3	0.4300	6.07	>99.5%
Betw. locations	3.821	9	0.4245	5.99	>99.95%
Species x loc.	1.771	25	0.0708	0.63	-
Remainder	0.679	6	0.1132		

5.4. Strontium-90 and Caesium-137 in Bread from the Entire Country

In 1973, samples of white bread (75% extraction) and dark rye bread (100% extraction) were collected all over the country in June. The samples were combined into eight zone samples and a sample from Copenhagen, and ^{90}Sr and ^{137}Cs were determined. The ^{137}Cs determinations were carried out on the ash by Ge γ-spectroscopy.

Tables 5.4.1 and 5.4.2 show the results. It is assumed that 1 kg flour yields approx. 1.35 kg bread[11] and that wheat flour of 75% extraction contains 20% of the ^{90}Sr and 50% of the ^{137}Cs found in wheat grain[1], while rye flour is 100% extraction hence we can compare the 1973 bread levels with the 1972 grain levels (cf. table 5.4.3).

Table 5.4.1

Strontium-90 in Danish bread in June 1973

Zone		White bread		Rye bread	
		pCi/kg	S.U.	pCi/kg	S.U.
I:	W. Jutland	7.6	4.4	36	13
II:	E. Jutland	6.9	4.2	30	15
III:	W. Jutland	6.8	8.2	34	11
IV:	S. Jutland	8.0	4.8	22	9
V:	Funen	9.1	5.8	36	16
VI:	Zealand	7.8	5.5	30	8
VII:	Lolland-Falster	6.9	2.4	20	6
VIII:	Bornholm	9.8	3.0	22	8
Mean		7.9	4.8	29	11
Copenhagen		12.5	4.3	28	11
Population-weighted mean		8.9	5.1	30	12

Table 5.4.2

Caesium-137 in Danish bread in June 1973

Zone		White bread		Rye bread	
		pCi/kg	M.U.	pCi/kg	M.U.
I:	N. Jutland	10.9	8.2	37	11.8
II:	E. Jutland	7.7 A	4.6 A	22	7.9
III:	W. Jutland	11.0	6.5	29	7.8
IV:	S. Jutland	9.6	6.6	24	7.1
V:	Funen	8.8	6.7	45	13.4
VI:	Zealand	9.6 A	6.5 A	28	7.3
VII:	Lolland-Falster	3.9 A	2.8 A	20	7.4
VIII:	Bornholm	7.8 A	5.2 A	28	7.0
Mean		8.7	5.9	29	8.7
Copenhagen		5.6 B	3.6 B	23	6.4
Population-weighted mean		8.3	5.5	28	8.2

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

Table 5.4.3 shows that the ^{90}Sr and ^{137}Cs levels in bread were higher than those in grain according to the above-mentioned model.

Table 5.4.3

A comparison ^{90}Sr and ^{137}Cs levels in bread and grain in 1973

Nuclide	Species	Bread activity in June 1973 calculated as grain in pCi/kg (cf. text)	Activity in grain from harvest 1972[1)] pCi/kg	"Bread"/grain ratio
^{90}Sr	Wheat	60	33	1.82
	Rye	40	29	1.38
^{137}Cs	Wheat	22	19	1.16
	Rye	39	37	1.03

5.5. Strontium-90 and Caesium-137 in Potatoes from the Entire Country

The samples of potatoes were collected in September from ten of the State experimental farms (cf. fig. 4.1.1) and analysed for ^{90}Sr and ^{137}Cs (γ-spectroscopy of bulked samples of the ash).

Table 5.5.1 shows the ^{90}Sr and ^{137}Cs contents in potatoes. The mean contents for the country were 3.9 pCi ^{90}Sr/kg or 98 S.U. and 5.4 pCi ^{137}Cs/kg or 1.0 M.U. Although the levels were higher than in 1972, they were not significantly different from those of last year.

The mean of the $^{137}Cs/^{90}Sr$ ratios (pCi/kg figures) was 1.4 (in 1972: 1.7, in 1971: 3.1, in 1970: 3.8, in 1969: 1.8, in 1968: 2.6, in 1967: 2.1, in 1966: 2.6, in 1965: 6, and in 1964: 9).

Table 5.5.1

Strontium-90 and Caesium-137 in Danish potatoes in 1973

	pCi ^{90}Sr/kg	S.U.	pCi ^{137}Cs/kg	M.U.
Tylstrup	2.4±0.0	109±1	6.6	1.7
Studsgård	2.8±0.2	86±4		
Ødum	4.6±0.1	52±1		
Askov	6.4±0.7	120±13		
St. Jyndevad	5.2±0.3	119±6		
Blangstedgård	3.1	55	4.2	0.9
Tystofte	2.6	127		
Ledreborg	5.6 A	80 A		
Abed	2.6	45		
Rønne	3.3	185		
Mean	3.9	98	5.4	1.0
A: relative S.D.: 20-33%				

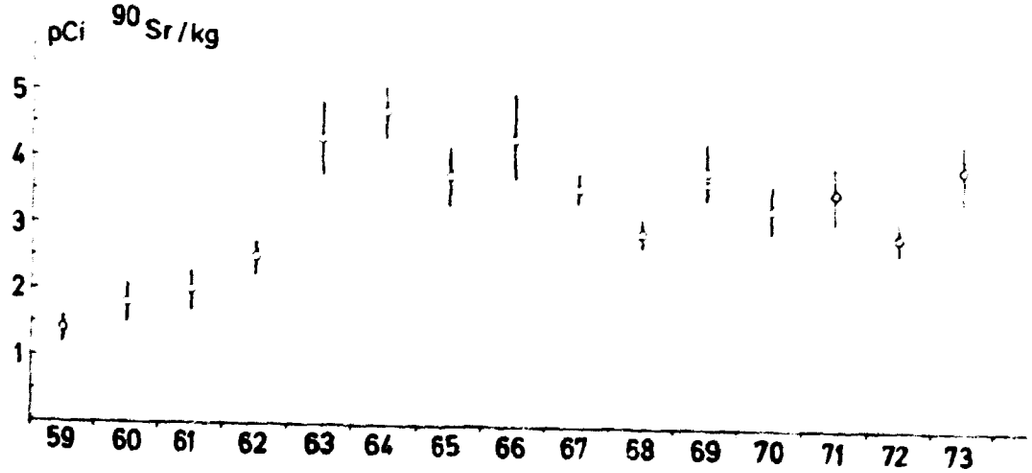


Fig. 5.5.1. Strontium-90 in Danish potatoes, 1959-73 (1 S.E. indicated)

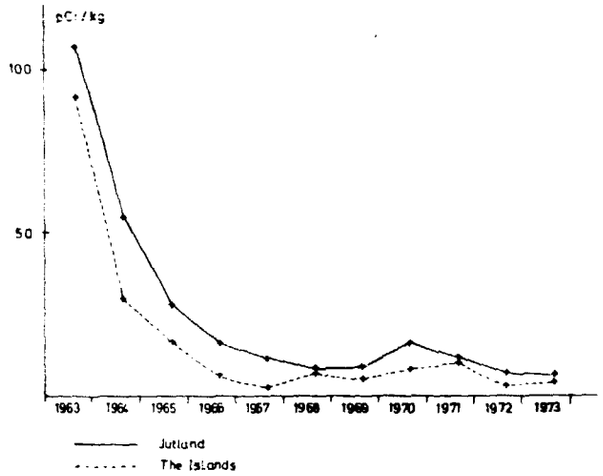


Fig. 5.5.2. Caesium-137 in potatoes from Jutland and the Islands, 1963-73

5.6. Strontium-90 and Caesium-137 in Vegetables and Fruits from the Entire Country

In 1973 as in previous years, vegetables and fruits were collected in September and December from eight greater provincial towns, one in each of the eight zones, and from Copenhagen.

Table 5.6.1

Strontium-90 in vegetables and fruits in 1973

Zone		Cabbage		Carrot		Onion		Apple		Pea	
		pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.	pCi/kg	S.U.
I:	N.Jutland	7.2	13.5	19.5	73	(14.2)	(49)	2.4	36	* 2.7	11.4
II:	E.Jutland	13.2	27.1	26.8±0.1	85±0	10.4	76	3.8	36	* 6.7	28.5
III:	W.Jutland	9.3	28.3	37.4	115	22.2	50	2.4	34	* 3.9	16.4
IV:	S.Jutland	4.8	9.4	11.7	44	7.0	22	1.5	29	* 2.8	11.7
V:	Funen	7.1	13.8	7.5	30	23.7	68	2.4	36	7.8	21.6
VI:	Zealand	10.8	21.5	6.6	19	12.6	30	3.2	35	4.0	12.6
VII:	Lolland-Falster	11.0	20.2	4.5	15	15.1	31	(2.9)	(37)	5.5	83.8
VIII:	Bornholm	3.5	6.0	7.8	22	18.6	42	5.8	59	3.6	8.3
Mean		8.4	17.5	15.2	50	15.5	46	3.0	32	4.6	24.3
Copenhagen		4.2	9.4	4.3	14	17.3	73	6.0	10	(3.5)	(10.1)
Population-weighted mean		8.2	17.9	15.0	49	15.8	57	3.8	29	4.5	17.6

*g Ca/kg calculated from 1969, 1970 and 1971.

Carrots and onions were collected in September, cabbages and apples in December, and peas were collected in July.

The Y-measurements were performed on bulked ash samples representing the entire country (cf. table 5.6.4). Tables 5.6.1 - 5.6.3 show the results and the analysis of variance of the ^{90}Sr determinations.

The variations between species were highly significant. The highest ^{90}Sr levels (pCi/kg) were found in onion, and carrot, the lowest in apple. The variation between locations was not significant.

Table 5.6.2

Analysis of variance of ln pCi ^{90}Sr/kg in vegetables and fruits in 1973 (from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	13.552	4	3.3880	11.72	>99.95%
Betw. locations	2.899	8	0.3624	1.25	-
Remainder	8.382	29	0.2890		

Table 5.6.3

Analysis of variance of ln S.U. in vegetables and fruits in 1973 (from table 5.6.1)

Variation	SSD	f	s^2	v^2	P
Betw. species	8.029	4	2.0072	5.85	>99.5%
Betw. locations	5.108	8	0.6385	1.86	-
Remainder	9.955	29	0.3433		

Table 5.6.4

Caesium-137 in vegetables and fruits in 1973

	Cabbage	Carrot	Onion	Apple	Pea
pCi/kg	2.0	2.0	0.9 B	3.1	*2.6 A
pCi/g K	0.7	0.8	0.4 B	2.1	0.8 A

*g K/kg calculated from 1969, 1970 and 1971.

A: relative S.D.: 20-33%

B: relative S.D.: > 33%

Fig. 5.6.1 shows the country wide mean pCi ^{90}Sr/g Ca levels in cabbage (white and red) and in carrots collected since 1961. The cabbage levels have since 1966 varied around 20 pCi ^{90}Sr/g Ca and the carrot levels have been between 50 and 60 pCi ^{90}Sr/g Ca, except in 1968 when the mean level was only 30 pCi ^{90}Sr/g Ca, (cf. discussion in Risø Report No. 291[1]).

The ^{90}Sr levels in cabbage and carrots depend primarily on the ^{90}Sr activity in the soil, during the last years approx. 95% of the ^{90}Sr came from the accumulated ^{90}Sr in the soil. The rather constant levels since 1966 are in accordance with the nearly constant soil levels (cf. 4.2) and support the statement put forward in Appendix C, that the availability of the ^{90}Sr in the soil for root uptake does not decrease so rapidly as suspected in 1971.

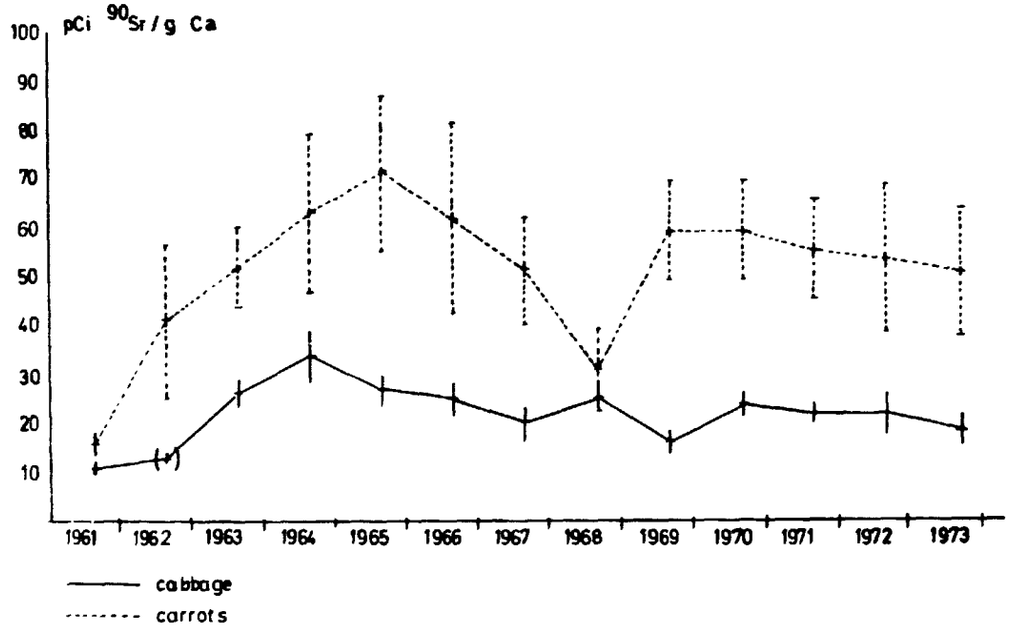


Fig. 5.6.1. Strontium-90 in Danish cabbage and carrots 1961-73 (1 S.E. indicated)

Fig. 5.6.2 shoes the corresponding curve for ^{137}Cs in cabbage and carrots, (notice that the ordinate is logarithmic). It is evident that ^{137}Cs in vegetables, unlike ^{90}Sr, depends strongly on the fall-out rate. It also appears that the levels in cabbage and carrots are similar, implying that the ^{137}Cs is translocated in carrots from above the soil parts to the roots.

Table 5.6.5 shows a calculation of the mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1973. The levels are the population-weighted means calculated in tables 5.6.1 - 5.6.4.

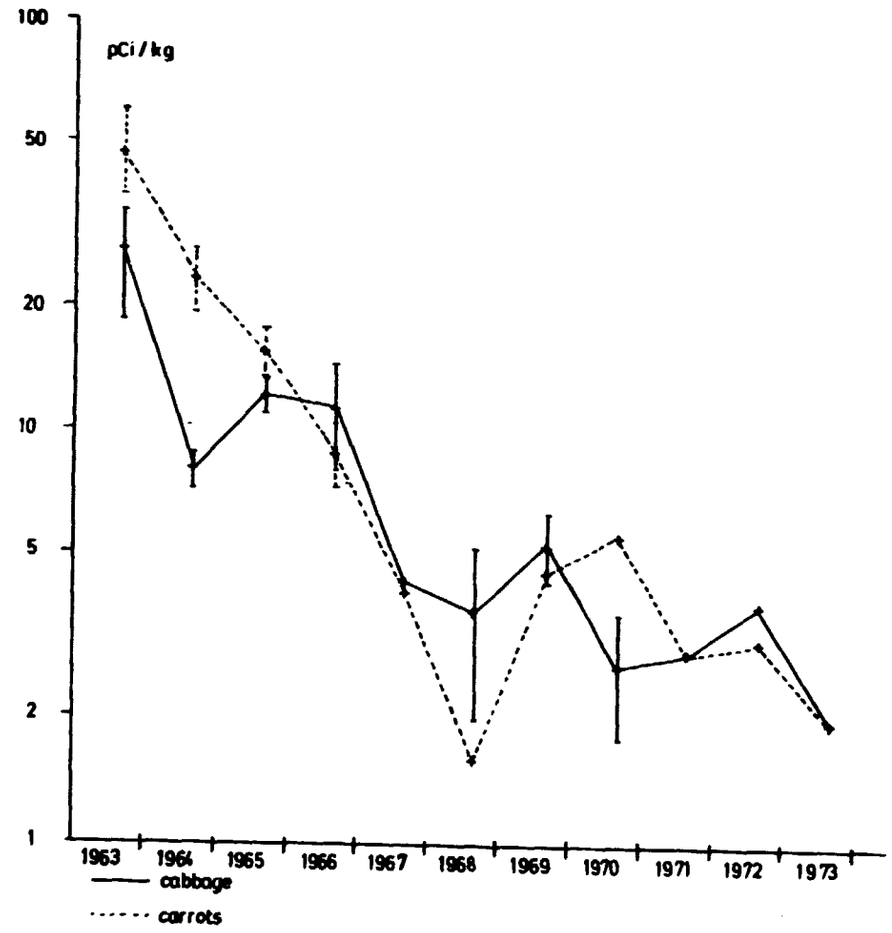


Fig. 5.6.2. Caesium-137 in Danish cabbage and carrots 1963-73
(1 S.E. indicated, when more than one deter nination was carried out)

Table 5.6.5

Calculated ^{90}Sr and ^{137}Cs mean levels in vegetables in 1973

Daily intake in g	Species	pCi ^{90}Sr per kg	S.U.	pCi ^{137}Cs per kg	M.U.
50	Leafy vegetables (cabbage)	8.2	17.9	2.0	0.7
30	Root vegetables (carrot, onion)	15.4	53.0	1.5	0.6
40	Pea	4.5	17.6	2.6	0.8
120	Vegetable total	8.8	26.6	2.1	0.7

The 1973 levels in Danish fruit were calculated from apples and the mean levels in Danish fruit were thus 3.8 pCi ^{90}Sr/kg and 3.1 ^{137}Cs/kg.

The 1973 ^{90}Sr levels in vegetables were a little lower and the ^{137}Cs levels significantly lower than the 1972 levels.

5.7. Strontium-90 and Caesium-137 in Total Diet from the Entire Country

In 1973 total-food samples representing an average Danish diet according to E. Hoff-Jørgensen (cf. Appendix B in Risø Report No. 63[1]) were collected from eight towns each representing one of the eight zones (cf. fig. 5.2.1) and from Copenhagen. The sampling took place as previously in June and December.

Tables 5.7.1 and 5.7.2 show the results. As in previous years, the variation between locations was significant. The S.U. levels in the total diet were approx. 15% higher in Jutland than in eastern Denmark.

Fig. 5.7.1 shows the zone mean levels (not population-weighted) of S.U. in total diet since May 1961. Fig. 5.7.2 shows the daily ^{137}Cs intake since June 1963.

The 1973 ^{90}Sr levels in total diet were approx. 8% lower than the 1972 levels, while the ^{137}Cs levels were approx. 40% lower than the 1972 ones.

From the total-diet sampling it is possible to estimate the mean levels of ^{90}Sr and ^{137}Cs in the Danish diet in 1973. For the period January-April 1973 the ^{90}Sr level in the total diet is assumed to have been equal to that measured in December 1972, Risø Report No. 291[1]. For the period May-September we assume the level to have corresponded to that measured in June 1973. The December 1973 figure is taken to represent the last three months of the year. The population-weighted mean of ^{90}Sr in total-diet

Table 5.7.1

Strontium-90 and Caesium-137 in Danish total diet collected in June 1973

Zone		pCi ^{90}Sr/g Ca	pCi ^{90}Sr/day	g Ca/day	pCi ^{137}Cs/g K	pCi ^{137}Cs/day
I:	N. Jutland	7.2±0.4 A	12.8±0.8 A	1.78±0.00	3.9	15
II:	E. Jutland	10.6±0.1	16.8±0.0	1.58±0.02	5.6	21
III:	W. Jutland	7.8±0.4	13.4±0.6	1.70±0.00	3.4	11
IV:	S. Jutland	8.5±0.0	12.4±0.0	1.45±0.01	4.0	14
V:	Funen	6.6±0.5	12.5±0.9	1.89±0.01	4.5	15
VI:	Zealand	6.8±0.5	13.5±0.8	1.97±0.02	3.2±0.4	11±2
VII:	Lolland-Falster	5.2±0.1	11.2±0.1	2.13±0.01	3.4	12
VIII:	Bornholm	9.9±0.4	21.2±0.7	2.14±0.02	3.1±0.1	12±1
Mean		7.8	14.2	1.83	3.9	14
Copenhagen		6.0±0.9	11.6±1.8	1.94±0.02	2.5 A	10
Population-weighted mean		7.5	13.4	1.82	3.7	13
Relative error due to analysis		8%	8%	1%		

A: relative S.D.: 20-33%

samples was 7.5 pCi ^{90}Sr/g Ca in December 1972. Hence the mean content in the total diet in 1973 was 7.3 pCi ^{90}Sr/g Ca or 12.6 pCi ^{90}Sr/day.

In a similar way the ^{137}Cs content in the Danish diet in 1973 was estimated to be 17 pCi ^{137}Cs/day or 3.2 pCi ^{137}Cs/g K (cf. also Appendix C).

Table 5.7.2

Strontium-90 and Caesium-137 in Danish total diet collected in December 1973

Zone		pCi ^{90}Sr/g Ca	pCi ^{90}Sr/day	g Ca/day	pCi ^{137}Cs/g K	pCi ^{137}Cs/day
I:	N. Jutland	7.4±0.3	12.6±0.5	1.71±0.01	5.2	18
II:	E. Jutland	6.8±0.1	11.8±0.2	1.74±0.02	3.0 A	12 A
III:	W. Jutland	7.4±0.2	12.4±0.6	1.68±0.04	4.9	17
IV:	S. Jutland	9.1±1.1	14.3±2.1	1.57±0.04	4.0	14
V:	Funen	5.7±0.2	10.4±0.7	1.83±0.05	3.4	13
VI:	Zealand	8.5±0.4	13.8±0.4	1.63±0.03	4.7	22±4
VII:	Lolland-Falster	7.6±0.8	14.6±1.6	1.92±0.01	2.9	12
VIII:	Bornholm	6.0±0.6	10.3±1.2	1.70±0.04	7.6±0.7	30±3
Mean		7.3	12.5	1.72	4.4	18
Copenhagen		5.1±0.7	9.3±1.5	1.84±0.04	4.7	18
Population-weighted mean		6.8	11.7	1.75	4.3	17
Relative error due to analysis		11%	12%	3%		

A: relative S.D.: 20-33%

Table 5.7.3

Stabile strontium in total diet in 1973
(mg Sr/g Ca)

Zone		June	Dec.
I:	N. Jutland	1.1±0.0	1.0±0.1
II:	E. Jutland	1.8±0.1	1.5±0.1
III:	W. Jutland	1.2±0.0	1.0±0.1
IV:	S. Jutland	1.5±0.4	0.8±0.0
V:	Funen	1.5±0.0	1.1±0.1
VI:	Zealand	1.9±0.1	1.0±0.1
VII:	Lolland-Falster	2.2±0.2	3.1±0.2
VIII:	Bornholm	1.0±0.0	0.9±0.0
Mean		1.5	1.4
Copenhagen		1.8±0.0	2.0±0.3

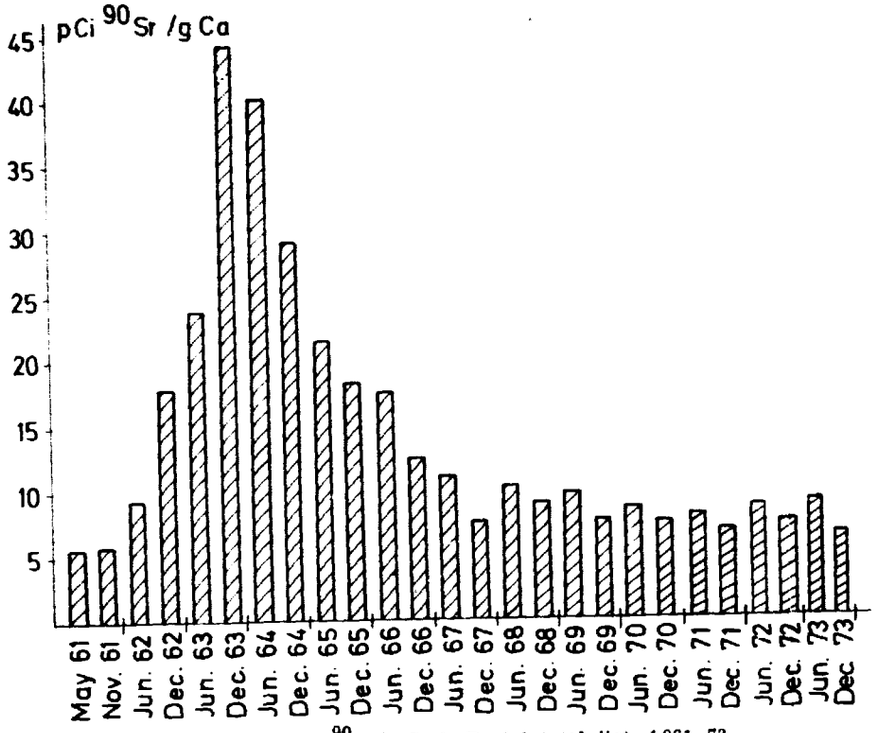


Fig. 5.7.1. pCi ^{90}Sr/g Ca in Danish total diet, 1961-73

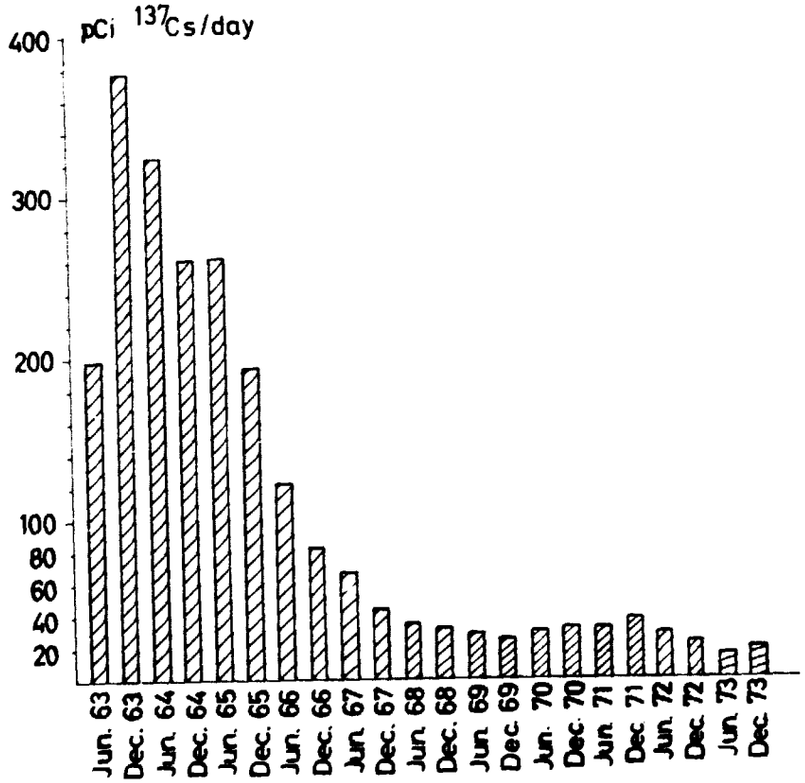


Fig. 5.7.2. pCi ^{137}Cs/day in Danish total diet, 1963-73

5.8. Strontium-90 and Caesium-137 in Miscellaneous Foodstoffs

5.8.1. Strontium-90 and Caesium-137 in Meat

Pork and beef samples were collected in Copenhagen in three big shops in March, June, September, and December. Table 5.8.1 shows the results. Figs. 5.8.1.1 and 5.8.1.2 show a comparison between milk and meat levels The ratio (pCi ^{90}Sr/kg meat)/(pCi ^{90}Sr/l milk) was 0.19 (S.E. 0.02), and the corresponding ratio for ^{137}Cs was 5.0 (S.E. 0.3) for the period 1962-1972. (In these calculations meat consisted of 2/3 pork and 1/3 beef) (cf. also Appendix C).

Table 5.8.1

Strontium-90 and Caesium-137 in pork and beef from Copenhagen in 1973

Species	Unit	March	June	Sep.	Dec.	Mean
Pork	pCi ^{90}Sr/kg	0.79	1.01 A	1.50 B	1.70 A	1.25
	pCi ^{90}Sr/g Ca	10.5	8.8 A	11.4 B	8.8 A	9.9
	pCi ^{137}Cs/kg	35	23 A	18	16 A	23
	pCi ^{137}Cs/g K	9.8	7.5 A	6.4	5.7 A	7.4
Beef	pCi ^{90}Sr/kg	1.31 A	3.83	1.26	1.40 A	1.95
	pCi ^{90}Sr/g Ca	11.1 A	19.9	13.8	8.2 A	13.2
	pCi ^{137}Cs/kg	12 B	24 A	22	14 A	18
	pCi ^{137}Cs/g K	3.7 B	7.9 A	6.8	4.8 A	5.8

A: Relative S.D.: 20-33%

B: Relative S.D.: >33%

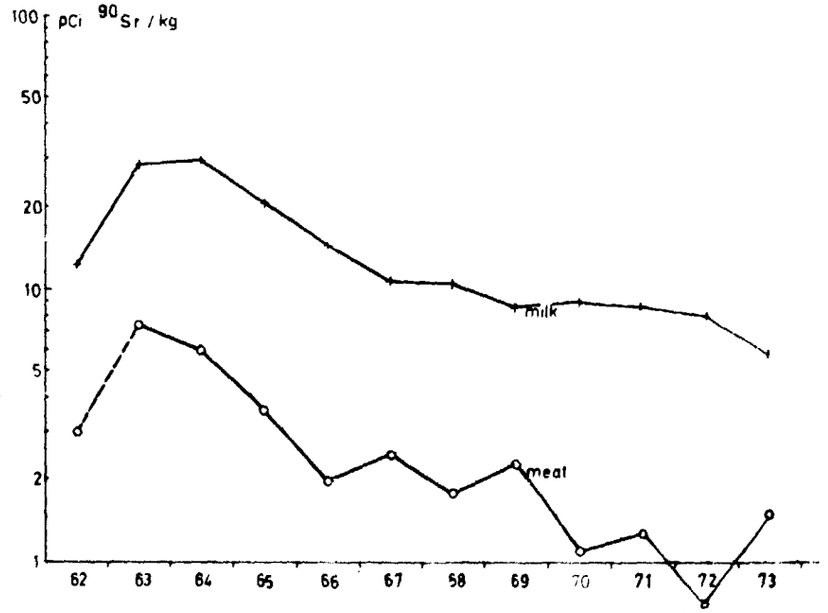


Fig. 5.8.1.1. Strontium-90 in Danish milk and meat (2/3 pork and 1/3 beef) 1962-73

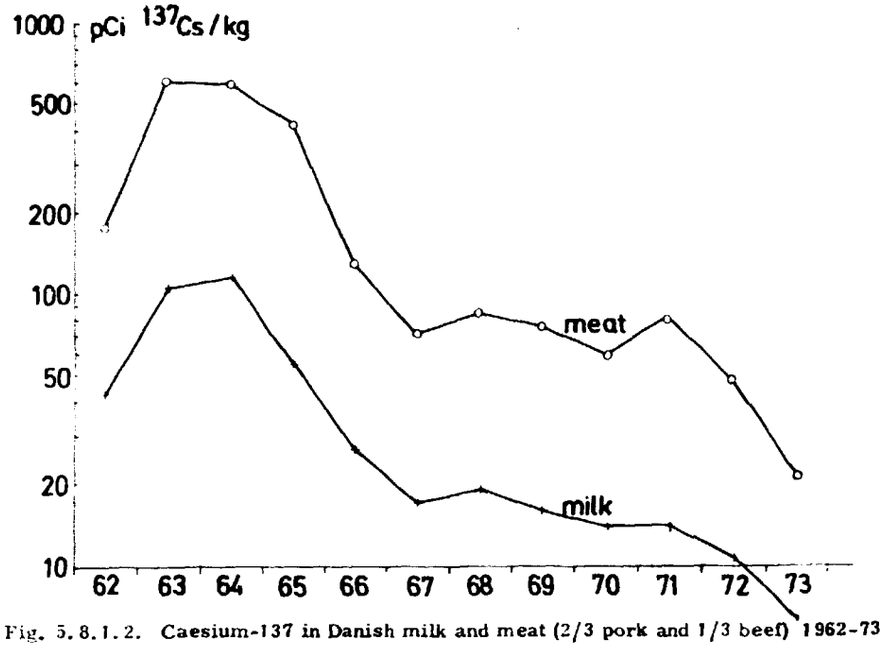


Fig. 5.8.1.2. Caesium-137 in Danish milk and meat (2/3 pork and 1/3 beef) 1962-73

5.8.2. Strontium-90 and Caesium-137 in Fish

Fish samples were collected in inner Danish waters along with the seawater sampling (cf. 7). Tables 5.8.2.1 - 5.8.2.4 show the results. We have also included data from previous years in the tables. Table 5.8.2.1

Table 5.8.2.1

Strontium-90 and Caesium-137 in fish collected in the Cattegat in September 1973

		^{90}Sr pCi/kg	^{90}Sr pCi/g Ca	^{137}Cs pCi/kg	^{137}Cs pCi/g K
Cod I	Meat	6.4	18.4	82	21
	Bone	-	15.4 A	-	-
Cod II	Total	7.3 A	0.66 A	50	21
Cod III	Meat	-	-	75	16
Lemon sole	Meat	3.6 A	10.3 A	44	14
	Bone	-	8.6	-	-
Whiting	Total	-	-	57	-
Hake	Total	-	-	68	18
Hake		-	-	32	-
Witch		-	-	40	-
Norway lobster	Meat	10.8 A	14.2 A	84	-
	Bone	-	6.2	-	-

contains besides the determinations of fish an analysis of Norway lobster. The mean levels in fish from 1973 were 54 $\pm$ 6 pCi ^{137}Cs/kg (9 samples) and 4.5 $\pm$ 1.5 pCi ^{90}Sr/kg (4 samples).

Table 5.8.2.2

Caesium-137 in fish collected at Barsebäck in October 1971

	^{137}Cs pCi/kg	^{137}Cs pCi/g K
Cod	32 B	7.8 B
Flounder I	26 A	9.1 A
Flounder II	27 A	7.5 A
Coalfish II	85	19.4
Coalfish III	138	32.8

A: relative S.D.: 20-33%

B: relative S.D.: > 33%

Table 5.8.2.3

Strontium-90 and Caesium-137 in eel collected in Roskilde Fjord in 1972 and 1973

		pCi ^{90}Sr/kg	pCi ^{90}Sr/g Ca	pCi ^{137}Cs/kg	pCi ^{137}Cs/g K
1972	Meat	1.3	3.1	42	15
	Bone	-	1.0	-	-
1973	Meat	0.5 B	1.1 B	42	13
	Bone	-	1.0	-	-

B: relative S.D.: > 33%

Table 5.8.2.4

Strontium-90 in total cod and fish bone collected in June 1971

		pCi ^{90}Sr/g Ca
Garfish Kalundborg	Bone	2.8
Herring Hundested	Bone	0.9
Cod Hundested	Bone	4.0
Cod Kerteminde	Total	1.2

Table 5.8.2.5 shows the ^{90}Sr level in shells of Mystilus edulis collected in the Southern and the Northern part of the Sound. There was no variation with size (i.e. age) in ^{90}Sr activity, probably because the sea water levels have been rather constant for the last 8 years (cf. fig. 7.1). However, there was a significant difference between the two locations. At the Southern location the mean salinity is approx. 11‰, and the mean ^{90}Sr level of the water is 0.73 pCi ^{90}Sr/l (mean of 1970-73) while the Northern station shows a mean salinity of approx. 22‰ and 0.52 pCi ^{90}Sr/l. It appears from the table that the observed ratio between S.U. in shells and sea water for both stations was about 0.16.

Table 5.8.2.5

Strontium-90 in shells from mussel (Mytilus edulis) in the Sound in 1973

Length of shell	Position	pCi ^{90}Sr/g Ca	pCi ^{90}Sr/g Ca in seawater 1970-1973	OR shell/seawater
0-2 cm	55°34'N 12°44'E	0.98±0.08	5.8	0.17
2-4 cm		0.97		
2-4 cm	55°47'N 12°44'E	0.28±0.04	1.9	0.15
4-8 cm		0.29±0.03		
The error term is the S.E. of double determinations.				

5.8.3. Strontium-90 in Drinking Water

Along with the total-diet samples, 60 l of drinking water was collected in June in each of the 8 towns (cf. figs. 5.2.1 and 5.2.2). The samples were analysed, by the method used for ground water, for ^{90}Sr, stable strontium, and calcium.

Table 5.8.3 shows the results. Ionexchanged water showed 0.0023 pCi ^{90}Sr/l. Hence we must conclude that the drinking water samples did not contain ^{90}Sr levels significantly above zero, Copenhagen and Bornholm being the only exceptions.

Table 5.8.3

Strontium-90 in Danish drinking water in June 1973

Zone		pCi ^{90}Sr/l	g Ca/l	mg Sr/g Ca
I:	N-Jutland	0.0037 B	0.080	1.22
II:	E-Jutland	0.0028 B	0.070	0.90
III:	W-Jutland	0.0030	0.081	1.93
IV:	S-Jutland	0.0024 A	0.074	3.00
V:	Funen	0.0055 A	0.140	4.22
VI:	Zealand	0.0044 A	0.092	10.32
VII:	Lolland-Falster	0.0038	0.091	17.05
VIII:	Bornholm	0.0125	0.036	1.80
Mean		0.0048	0.083	5.06
Copenhagen		0.0678	0.115	6.15
Median of zones		0.0037	0.081	2.46
A: Relative S.D.: 20-33%				
B: Relative S.D.: > 33%				

5.9. Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Human Diet in Denmark in 1973

5.9.1. The Annual Quantities

The annual quantities are calculated by multiplication of the daily quantities (as stated by E. Hoff-Jørgensen, cf. Risø Report No. 63, table B[1]) by 365.

5.9.2. Milk and Cream

The ^{90}Sr and ^{137}Cs contents per kg milk were calculated from the annual mean values for dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg ~ 1 l milk, containing approx. 1.2 g Ca and 1.66 g K. Hence the mean contents in milk were 5.6 pCi ^{90}Sr/kg and 6 pCi ^{137}Cs/kg.

5.9.3. Cheese

1 kg of cheese contains approx. 8.5 g Ca and 1.2 g K. The ^{90}Sr and ^{137}Cs contents in cheese were calculated from these figures and from the S.U. and M.U. levels in dried milk (cf. tables 5.1.1 and 5.1.3). 1 kg of cheese appeared to contain 40 pCi ^{90}Sr and 4 pCi ^{137}Cs.

5.9.4. Grain Products

Tables 5.9.1 and 5.9.2 show the estimates of ^{90}Sr and ^{137}Cs respectively in grain products consumed in 1973. From these tables the activity levels in grain products were estimated at 15.4 pCi ^{90}Sr/kg and 17 pCi ^{137}Cs/kg.

Table 5.9.1

Estimate of the ^{90}Sr content in grain products consumed per capita in 1973

Type	Fraction from harvest 1972			Fraction from harvest 1973			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	29	635	7.3	26	190	825
Wheat flour (75% extraction)	32.9	6.6	217	10.9	3.8	41	258
Grits	5.5	23.2	128	1.8	14.4	26	154
Total	60.3	16.3	980	20.0	12.9	257	1237

Table 5.9.2

Estimate of the ^{137}Cs content in grain products consumed per capita in 1973

Type	Fraction from harvest 1972			Fraction from harvest 1973			Total
	kg flour	pCi/kg	pCi	kg flour	pCi/kg	pCi	pCi
Rye flour (100% extraction)	21.9	37	810	7.3	11.8	86	896
Wheat flour (75% extraction)	32.9	9.4	309	10.9	3.8	41	350
Grits	5.5	18.5	102	1.8	8.8	16	118
Total	60.3	20	1221	20.0	7.2	143	1364

5.9.5. Potatoes

The figures in table 5.5.1 were used, i.e. 3.9 pCi ^{90}Sr/kg and 5.4 pCi ^{137}Cs/kg.

5.9.6. Vegetables

Table 5.6.5 shows the calculation of ^{90}Sr and ^{137}Cs in Danish vegetables consumed in 1973. The mean contents were 8.8 pCi ^{90}Sr/kg and 2.1 pCi ^{137}Cs/kg.

5.9.7. Fruit

The levels in imported fruit in 1973 are assumed to be equal to the mean levels found in lemons, oranges, and bananas collected in Copenhagen in 1972[1], i.e. 3.4 pCi ^{90}Sr/kg and 1.3 pCi ^{137}Cs/kg. The mean levels in Danish fruit in 1973 were 3.8 pCi ^{90}Sr/kg and 3.1 pCi ^{137}Cs/kg (cf. 5.6). The daily mean consumption of fruit consisted of 100 g of Danish and 40 g of foreign origin. Hence the mean contents in fruit were 3.7 pCi ^{90}Sr/kg and 2.6 pCi ^{137}Cs/kg.

5.9.8. Meat

From table 5.8.1 the annual mean values of ^{90}Sr and ^{137}Cs in meat were calculted: 1.5 pCi ^{90}Sr/kg and 21 pCi ^{137}Cs/kg. (Danish meat consists of 2/3 pork and 1/3 beef).

5.9.9. Fish

The ^{90}Sr and ^{137}Cs contents in fish are estimated from 5.8.2, at 4.5 pCi ^{90}Sr/kg and 54 pCi ^{137}Cs/kg (mean of all fishsamples collected in 1973).

5.9.10. Eggs

The activity contents in eggs were estimated from last years estimate. The levels were 2 pCi ^{90}Sr/kg and 4 pCi ^{137}Cs/kg.

5.9.11. Coffee and Tea

A third of the total consumption consists of tea and two thirds of coffee. The mean contents from 1972[1] were used: 23.6 pCi ^{90}Sr/kg and 106 pCi ^{137}Cs/kg.

5.9.12. Drinking Water

The ^{90}Sr level (population weighted mean) found in drinking water collected in June (cf. table 5.8.3) was used as the mean level for drinking water, i.e. 0.02 pCi ^{90}Sr/l. The ^{137}Cs content in drinking water is assumed to be negligible, because we can not detect it even in surface fresh water (cf. 4.4).

5.9.13. Discussion

Tables 5.9.3 and 5.9.4 show the estimates of ^{90}Sr and ^{137}Cs in the Danish diet in 1973. The figures should be compared with the levels calculated from the total-diet samples (cf. 5.7). The ^{90}Sr estimates obtained by the two methods were 5.9 S.U. and 7.3 S.U. respectively, and the ^{137}Cs estimates were 15 pCi ^{137}Cs/day and 17 pCi ^{137}Cs/day. The deviation between the two estimates for ^{90}Sr is ascribed to the disagreement between the actual ^{90}Sr levels in bread and those calculated from grain (cf. table 5.4.3).

The relative contribution of ^{90}Sr from milk products was nearly unchanged compared with 1972 (~35%), whereas that from grain products decreased from 43 to 34%. The contribution from potatoes, other vegetables, and fruit was 24%, against 17% in 1972. The relative contribution of ^{137}Cs in the total diet changed as follows from 1971 to 1972: Milk products were nearly unchanged ~19%, grain products decreased from 41 to 25%, and meat were nearly unchanged ~21%.

Table 5.9.3

Estimate of the mean content of ^{90}Sr in the human diet in Denmark in 1973

Type of food	Annual quantity in kg	pCi ^{90}Sr per kg	Total pCi ^{90}Sr	Percentage of total pCi ^{90}Sr in food
Milk and cream	164.0	5.6	918	25.0
Cheese	9.1	40.0	364	9.9
Grain products	80.3	15.4	1237	33.6
Potatoes	73.0	3.9	285	7.8
Vegetables	43.8	8.8	385	10.5
Fruit	51.1	3.8	194	5.3
Meat	54.7	1.5	82	2.2
Eggs	10.9	2.0	22	0.6
Fish	10.9	4.5	49	1.3
Coffee and tea	5.5	23.5	130	3.5
Drinking water	548	0.02	11	0.3
Total			3677	

The mean calcium intake was estimated at 620 g (approx. 200-250 g Creta praeparata). Hence the ^{90}Sr/Ca ratio in the total diet was 5.9 S.U. in 1973.

Table 5.9.4

Estimate of the mean content of ^{137}Cs in the human diet in Denmark in 1973

Type of food	Annual quantity in kg	pCi ^{137}Cs per kg	Total pCi ^{137}Cs	Percentage of total pCi ^{137}Cs in food
Milk and cream	164.0	6.0	984	18.3
Cheese	9.1	4.0	36	0.7
Grain products	80.3	17.0	1364	25.4
Potatoes	73.0	5.4	397	7.4
Vegetables	43.8	2.1	92	1.7
Fruit	51.1	2.6	133	2.5
Meat	54.7	21.0	1149	21.4
Eggs	10.9	4.0	44	0.8
Fish	10.9	54.0	589	11.0
Coffee and tea	5.5	106	583	10.8
Drinking water	548	0	0	0
Total			5371	

As the approximate intake of potassium was 1365 g, the pCi ^{137}Cs/g K ratio was approx. 3.9. The daily mean intake in 1973 was 15 pCi ^{137}Cs per capita.

It is evident that the food components which depends mostly on the fall-out rate (e.g. grain products) have decreased markedly compared to previous years. The decrease is as expected most pronounced for ^{137}Cs, due to the very low root uptake from Danish soils. We may notice the increasing relative importance of fish as a ^{137}Cs donor in the human diet, this trend has been predicted in an earlier publication[17].

6. STRONTIUM-90 AND CAESIUM-137 IN MAN IN 1973

6.1. Strontium-90 in Human Bone

The collection of human vertebrae from the institutes of forensic medicine in Copenhagen and Århus was continued in 1973. As in the total-food survey (cf. 5.7), the country was divided into eight zones. The samples were divided into five age groups: new-born (<1 month), infants (1 month-4 years), children and teen-agers (5 - 19 years), adults (≤29 years) and adults (> 29 years).

Tables 6.1.1 - 6.1.5 show the results for the five groups.

Table 6.1.1

Strontium-90 in bone from new-born children (< 1 month old) in 1973

Zone	Age in days	Month of death	Sex	pCi ^{90}Sr/g Ca
II	8	10	M	1.44 A
VI	0-6	2-9	F	2.32*

A: Relative S.D.: 20-33%
*4 samples combined in one analysis.

Table 6.1.2

Strontium-90 in bone from infants (≤ 4 years old) in 1973

Zone	Age in years and months	Month of death	Sex	pCi ^{90}Sr/g Ca
II	3 m	8	M	2.00
II	7 m	6	M	2.08
II	1 y	9	M	2.02
II	1-3 m	6-10	F	0.51*
II	2.5 y	7	F	1.26
VI	2 m	10	F	1.20
VI	2-3 m	2-12	F	1.51*
VI	3-6 m	3-11	F	3.26▽
VI	14-18 m	3-8	F	1.14*

*4 samples combined in one analysis
▽6 samples combined in one analysis

Table 6.1.3

Strontium-90 in bone from children and teen-agers (≤ 19 years) in 1973

Zone	Age in years	Month of death	Sex	pCi ^{90}Sr/g Ca
I	10	6	F	1.99 A
II	16	7	F	1.35
II	17	9	F	2.31
II	18	7	F	1.30 A
II	19	8	F	1.13
II	6	12	M	1.21
II	8	6	M	1.64
II	16	9	M	2.13
VI	7	5	F	1.45 A
VI	10	4	F	1.58
VI	12	11	F	1.25
VI	13	3	F	2.44
VI	14	9	F	1.03 A
VI	15	6	F	1.30 A
VI	15	12	F	1.65 A
VI	16	2	F	0.91 B
VI	16	3	F	5.05
VI	17	12	F	1.31 A
VI	17	1	F	1.33
VI	18	10	F	3.43
VI	18	7	F	1.55
VI	19	3	F	2.44
VI	19	9	F	1.10
VI	19	10	F	1.83
VI	6-7	3-11	M	1.40*
VI	10	5	M	1.15
VI	9-10	7-11	M	1.41*
VI	13	12	M	1.07 A
VI	13	9	M	2.35
VI	13	10	M	0.52 B
VI	17	9	M	1.75
VI	17	11	M	0.98 A
VI	18	3	M	1.74
VI	18	3	M	1.27
VI	19	12	M	1.12
VI	19	10	M	1.04

*2 samples combined in one analysis
A: Relative S.D.: 20-33%
B: Relative S.D.: > 33%

Table 6.1.4

Strontium-90 in vertebrae from adults (≤ 29 years) in 1973

Zone	Age in years	Month of death	Sex	pCi ^{90}Sr/g Ca
II	20	8	F	1.28
II	21	10	F	1.37
II	24	8	F	2.20
II	29	9	F	1.31 A
II	24	9	M	1.94
III	26	6	M	2.17
VI	20	3	F	1.56
VI	21	7	F	1.29
VI	21	10	F	1.68 A
VI	22	7	F	1.87 A
VI	23	6	F	1.01
VI	23	9	F	1.59 A
VI	23	7	F	1.48
VI	23	10	F	1.42 A
VI	23	10	F	1.34
VI	24	12	F	0.52 A
VI	24	7	F	1.49
VI	25	10	F	1.36
VI	27	3	F	1.06
VI	20	8	M	0.98
VI	21	9	M	1.95
VI	22	3	M	2.72
VI	22	10	M	1.60
VI	24	6	M	1.40
VI	25	3	M	1.58 A
VI	28	6	M	0.48
VI	28	4	M	2.01
VI	29	12	M	1.15 A

A: Relative S.D.: 20-33%

Table 6.1.5

Strontium-90 in vertebrae from adults (> 29 years old) in 1973

Zone	Age in years	Month of death	Sex	pCi ^{90}Sr/g Ca
I	65	8	F	3.50
I	75	11	F	1.83
I	36	11	M	0.98
I	70	8	M	1.66
II	39	10	F	1.05 A
II	39	11	F	0.79 A
II	40	7	F	1.40
II	47	9	F	1.18
II	50	6	F	2.04
II	52	10	F	1.34
II	53	11	F	2.27 B
II	53	11	F	1.18
II	54	12	F	1.68
II	66	7	F	1.18
II	70	8	F	0.72
II	71	10	F	1.47
II	74	8	F	1.36
II	75	10	F	2.34
II	77	12	F	1.24
II	79	12	F	3.60
II	81	9	F	3.19
II	42	8	M	2.29
II	42	8	M	1.31
II	45	9	M	1.09
II	52	7	M	1.28 B
II	56	6	M	1.90
II	60	9	M	1.97
II	60	10	M	1.61 B
II	62	9	M	0.84 A
II	62	12	M	2.08
II	64	11	M	1.43
II	65	10	M	1.46
II	71	12	M	3.42
II	81	6	M	1.23
III	47	6	F	2.40
III	54	7	F	1.70
III	70	9	F	1.61
IV	35	8	M	2.17
VI	34	11	F	0.95 A
VI	56	4	F	1.07
VI	30	5	M	1.44
VI	34	11	M	1.28
VI	39	12	M	0.86

A: Relative S.D.: 20-33%

B: Relative S.D.: > 33%

Table 6.1.6

Strontium-90 (pCi/g Ca) in human vertebrae collected in Denmark in 1973

Age group	Number of samples	Number of analysis	Min.	Max.	Median	Mean of analysis	Sample number weighted mean
New-born (< 1 month)	5	2	1.44	2.32	1.88	1.88	2.14
Infants (≤ 4 years)	23	9	0.51	3.26	1.51	1.66	1.77
Children (≤ 19 years)	38	36	0.52	5.05	1.38	1.63	1.62
Adults (≤ 29 years)	28	28	0.48	2.72	1.45	1.49	1.49
Adults (≥ 30 years)	43	43	0.72	3.60	1.44	1.66	1.66

Table 6.1.7

Strontium-90 in human bone in 1972

Zone	Age	Month of death	Sex	pCi ^{90}Sr/g Ca
VI	21 years	3	F	1.11 A
VI	21 years	11	F	1.32 A
VI	21 years	11	F	3.63 A
VI	22 years	2	F	2.45
VI	22 years	4	F	1.63
VI	23 years	3	F	2.11
VI	23 years	5	F	1.10
VI	25 years	9	F	2.86
VI	27 years	3	F	3.65

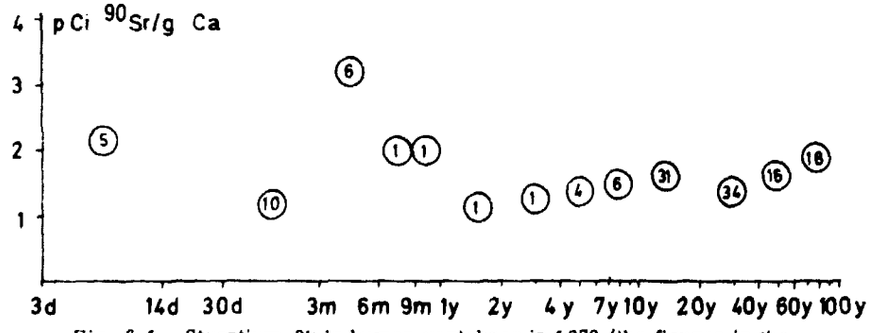


Fig. 6.1. Strontium-90 in human vertebrae in 1973 (the figures in the circles indicate the number of samples)

The levels were generally a little lower in 1973 than in 1972. The highest mean level in vertebrae were found in the newborn, but the levels in the different agegroups were nearly the same.

6.2. Caesium-137 in the Human Body

In July 1963, whole-body measurements were initiated at Risø in the low-level counting room in the Health Physics Department (cf. 2.3 in Risø Report No. 85[1]). A control group from the Health Physics Department was selected and has since then been measured three times a year. Table 6.2 shows the results.

Table 6.2

Whole-body measurements of caesium-137 and potassium in 1973

No.	Sex	Counting date	Age	Height in cm	Weight in kg	pCi ^{137}Cs/g K	pCi ^{137}Cs/kg	g K/kg body weight
2	F	April	25	165	53	24.7	47.0	1.9
3	F	-	41	178	64	5.3	8.8	1.7
7	F	-	45	171	65	14.6	23.7	1.6
8	M	-	41	193	80	19.1	39.6	2.1
9	M	-	45	170	67	8.0	15.4	1.9
12	M	-	35	174	75	13.0	24.5	1.9
19	M	-	31	174	73	13.3	26.4	2.0
20	M	-	41	172	64	18.4	40.2	2.2
21	F	-	52	176	67	9.0	13.7	1.5
22	M	-	50	183	74	7.7	16.7	2.2
23	M	-	43	192	88	14.3	28.2	2.0
24	M	-	42	170	74	14.9	32.0	2.1
26	F	-	34	160	56	16.3	29.1	1.8
30	F	-	27	168	58	9.5	21.6	2.3
31	M	-	31	182	77	27.4	54.8	2.0
32	F	-	44	157	58	3.5	6.1	1.8
33	M	-	42	184	64	16.3	37.9	2.3
34	M	-	31	177	72	13.3	30.0	2.3
35	M	-	32	181	70	20.4	40.1	2.0
42	M	-	45	172	61	6.9	15.5	2.2
43	M	-	56	167	69	6.1	11.4	1.9
44	F	-	23	170	58	8.1	13.2	1.6
46	M	-	45	176	73	17.8	35.8	2.0
47	M	-	32	176	78	7.2	16.2	2.3
48	F	-	34	162	50	2.6	4.9	1.9
49	M	-	61	168	80	16.1	29.0	1.8
50	M	-	25	169	65	9.9	22.0	2.2
4	F	Aug.	49	161	60	6.3	7.5	1.2
7	F	-	45	171	64	5.9	8.5	1.4
8	M	-	41	193	78	14.7	27.7	1.9

(6.2 continued)

No.	Sex	Counting date	Age	Height in cm	Weight in kg	pCi ^{137}Cs/g K	pCi ^{137}Cs/kg	g K/kg body weight
12	M	Aug.	35	174	75	7.6	13.1	1.7
19	M	-	31	174	73	10.2	21.7	2.1
20	M	-	41	172	64	12.5	24.0	1.9
21	F	-	52	176	63	18.3	29.5	1.6
22	M	-	50	183	74	8.7	16.8	1.9
23	M	-	43	192	85	8.1	14.2	1.7
24	M	-	42	170	74	19.1	32.2	1.7
26	F	-	34	160	56	4.5	7.5	1.7
30	M	-	27	168	58	11.2	22.5	2.0
33	M	-	42	184	63	10.1	21.6	2.1
35	M	-	32	181	68	12.7	21.7	1.7
42	M	-	45	172	58	10.1	21.5	2.1
45	F	-	26	167	57	9.7	21.0	2.2
47	M	-	32	176	78	7.0	12.6	1.8
48	F	-	34	162	50	2.4	4.4	1.8
49	M	-	61	168	75	10.1	17.8	1.8
51	M	-	41	175	85	4.8	9.8	2.0
1	F	Dec.	23	160	57	15.1	32.9	2.2
2	F	-	25	165	52	15.1	30.3	2.0
4	F	-	49	161	61	24.2	41.5	1.7
8	M	-	41	193	80	15.4	27.5	1.8
19	M	-	34	178	78	6.5	12.2	1.9
19	M	-	31	174	72	10.4	20.0	1.9
20	M	-	41	172	67	12.0	22.8	1.9
22	M	-	50	183	74	7.7	17.9	2.3
24	M	-	42	170	76	8.7	17.0	2.0
26	F	-	34	160	55	11.4	18.7	1.6
30	M	-	27	168	61	13.6	28.5	2.1
31	M	-	31	182	72	12.1	27.1	2.2
43	M	-	56	167	70	3.3	6.3	1.9
46	M	-	45	176	78	6.4	12.7	2.0
47	M	-	32	176	78	7.0	15.1	2.2
48	F	-	34	162	50	8.6	19.4	2.3
49	M	-	61	168	80	2.6	4.0	1.6
51	M	-	41	175	86	9.3	14.0	1.5
52	F	-	36	173	55	22.8	46.7	2.0
53	F	-	48	154	85	5.3	7.1	1.3
90	M	-	52	185	111	7.6	12.6	1.6

The annual mean value of the control group was 11 pCi ^{137}Cs/g K. As earlier, we shall consider this figure representative of the mean of the Danish population in 1973. The total-body content of ^{137}Cs in 1972 for a standard man containing 140 g of potassium equals $140 \cdot 11 \cdot 10^{-3}$ nCi = 1.5 nCi ^{137}Cs, i.e. 70% of the 1972 level.

Fig. 6.2 shows the mean M.U. values (with one S.D.) for men and women measured in 1963-1973.

The maximum was reached in August 1964. The figure also shows that the mean level in the male group was approx. 1.3 - 1.5 times as high as that in the female group.

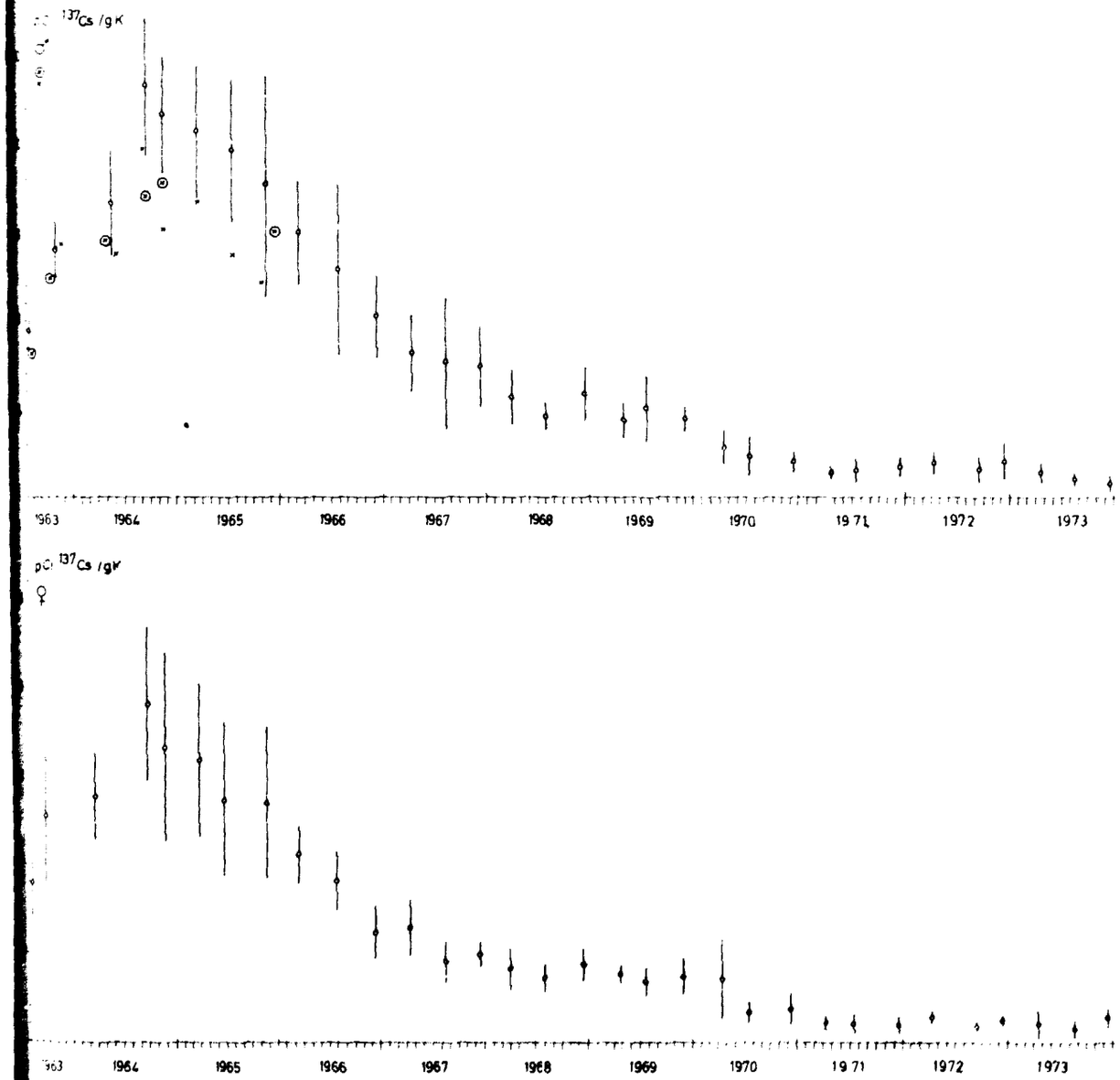


Fig. 6.2. Caesium-137 mean levels in humans, 1963-73 (1 S.D. indicated)

7. STRONTIUM-90 AND CAESIUM-137 IN SEA WATER IN 1973

Collecting of sea water samples, as initiated in 1961-62, was continued in 1973. M/S Fyrholm collected samples at the locations around Zealand (cf. fig. 7.2) in May and November. Table 7.1 and fig. 7.1 show the results.

Table 7.1

	Position		May				November			
	N	E	depth in m	^{90}Sr pCi/l	Salinity o/oo	^{137}Cs pCi/l	depth in m	^{90}Sr pCi/l	Salinity o/oo	^{137}Cs pCi/l
Kullen	56°15'	12°25'	0	0.86	9.05	0.85	0	0.87	20.2	0.76
"			22	-	32.8	0.94	27	0.56	33.4	0.90
Hesselø	56°10'	11°47'	0	0.84	14.4	0.83	0	0.68	27.8	1.22
"			24	0.43	32.7	1.07	27	0.52	27.8	0.76
Kattegat SW	56°07'	11°10'	0	0.71	15.2	1.04	0	0.73	26.6	1.16
"			47	0.33	32.0	0.79	30	0.74	29.0	1.06
Asnæs rev	55°38'	10°47'	0	0.66	12.0	0.71	0	0.61	25.1	1.09
" "			-	-	-	-	45	0.54	26.2	0.97
Halskov rev	55°20'	11°02'	0	0.50	9.9	0.76	0	0.56	25.1	1.07
" "			49	0.36	31.2	0.96	45	0.60	25.2	1.07
Langeland belt	54°52'	10°50'	-	-	-	-	0	0.85	24.7	1.05
" "			44	0.41	32.0	0.62	47	0.58	25.0	1.10
Femern belt	54°36'	11°05'	0	0.81	10.7	0.76	0	0.83	20.7	0.66
" "			27	0.43	21.4	0.73	26	0.60	22.0	0.82
Gedser rev	54°28'	12°13'	0	1.00	8.4	0.78	0	0.68	19.3	0.64
" "			27	0.53	17.2	0.71	24	0.79	19.9	0.90
Møen	54°57'	12°41'	0	-	8.3	0.64	0	1.13	10.7	0.78
"			20	0.78	9.3	0.65	20	0.66	17.9	0.94
The Sound - south	55°25'	12°39'	0	0.48	8.4	0.89	0	0.67	11.1	0.74
" " "			12	1.05	8.3	0.45	12	0.63	15.9	0.83
The Sound - north A	55°48'	12°44'	0	0.78	8.7	0.72	0	0.84	21.4	0.93
" " "			23	0.35	32.4	0.96	20	0.61	31.2	1.12
The Sound - north B	55°59'	12°42'	0	0.65	8.8	0.74	0	0.60	20.8	0.96
" " "			27	0.25	33.0	0.89	28	0.66	32.4	1.24
Mean			Surface	0.73	10.4	0.79	Surface	0.75	21.1	0.92
SD				0.16	2.5	0.11		0.16	5.5	0.20
SE				0.05	0.7	0.03		0.05	1.6	0.06
Mean			Bottom	0.49	25.7	0.80	Bottom	0.62	25.4	0.98
SD				0.24	9.8	0.18		0.08	5.7	0.14
SE				0.08	3.0	0.06		0.02	1.6	0.04

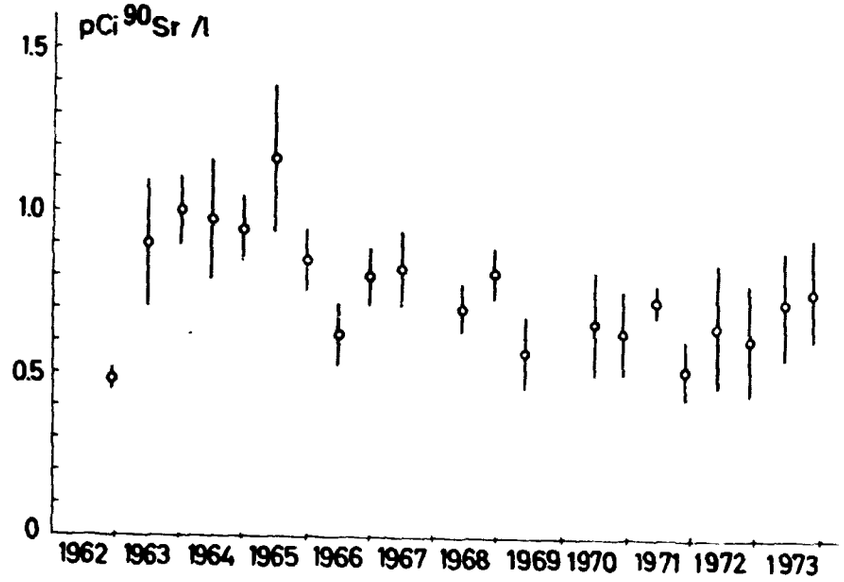


Fig. 7.1. Strontium-90 in surface sea-water from inner Danish waters, 1962-73 (1 S.D. indicated). (From table 7.1)

It is remarkable that both ^{90}Sr and ^{137}Cs levels were higher than those of last year. We have at present no definitive explanation for this unexpected increase. We believe that the rather high levels in the North Sea (cf. table 7.4) could be responsible to some degree. This is supported by the fact that especially the water of high salinity showed high ^{137}Cs levels. We know that the North Sea is polluted with ^{90}Sr and especially ^{137}Cs from British and French nuclear plants (cf. below and Risø Report No. 291[1]). Table 7.2 shows the levels in the samples collected in the Sound at Barsebäck in 1973, and in table 7.3 we find samples collected in the Kattegat at Ringhals. The results from these tables are included in fig. 7.3. We calculated a regression equation for 1973: pCi ^{90}Sr/l = 0.95 - 0.014‰, however, the variation of activity with salinity was not significant.

As in 1972, the ^{137}Cs/^{90}Sr ratio was positively correlated with the salinity. Contrary to last year, however, a regression analysis could not prove any significant variation of the ratio with salinity. Fig. 7.4 shows that especially the samples with high salinity showed higher ^{137}Cs/^{90}Sr ratios in 1973 than in 1972. From table 7.1 it appears that no high salinity samples from the November sampling around Zealand showed extreme ratios.

Table 7.2

Strontium-90 and Caesium-137 in sea water collected in the Sound (Ratsebäck) in 1973

Position		Feb.-March				May				November			
N	E	depth in m	^{90}Sr pCi/l	^{137}Cs pCi/l	Salinity o/oo	depth in m	^{90}Sr pCi/l	^{137}Cs pCi/l	Salinity o/oo	depth in m	^{90}Sr pCi/l	^{137}Cs pCi/l	Salinity o/oo
55°42'08"	12°54'	0	1.06	0.48	9.4	0	-	0.95	8.7	0	0.60	0.84	24.6
- " -	- " -	13	0.69	0.51	13.2	14	0.42	0.81	24.6	14	0.51	0.86	26.4
55°47'05"	12°51'07"	0	1.08	0.53	9.4	0	0.65	0.69	8.6	0	0.89	0.63	27.1
- " -	- " -	16	0.59	0.63	22.0	15	0.30	0.99	28.2	21	0.67	1.06	29.9
54°52'	10°50'	0	0.77	0.73	9.0								
55°38'	10°47'	47	0.38	0.93	32.0								
Mean		Surface	0.97	0.58	9.3	Surface	0.65	0.82	8.6	Surface	0.74	0.74	25.8
SD			0.17	0.13	0.2			0.18	0.1		0.20	0.15	1.8
SE			0.10	0.08	0.1			0.13	0.0		0.14	0.10	1.2
Mean		Bottom	0.55	0.69	22.4	Bottom	0.36	0.90	20.7	Bottom	0.59	0.96	28.2
SD			0.16	0.22	9.4		0.08	0.13	10.0		0.11	0.14	2.5
SE			0.09	0.12	5.4		0.06	0.09	5.8		0.08	0.10	1.8

Table 7.3

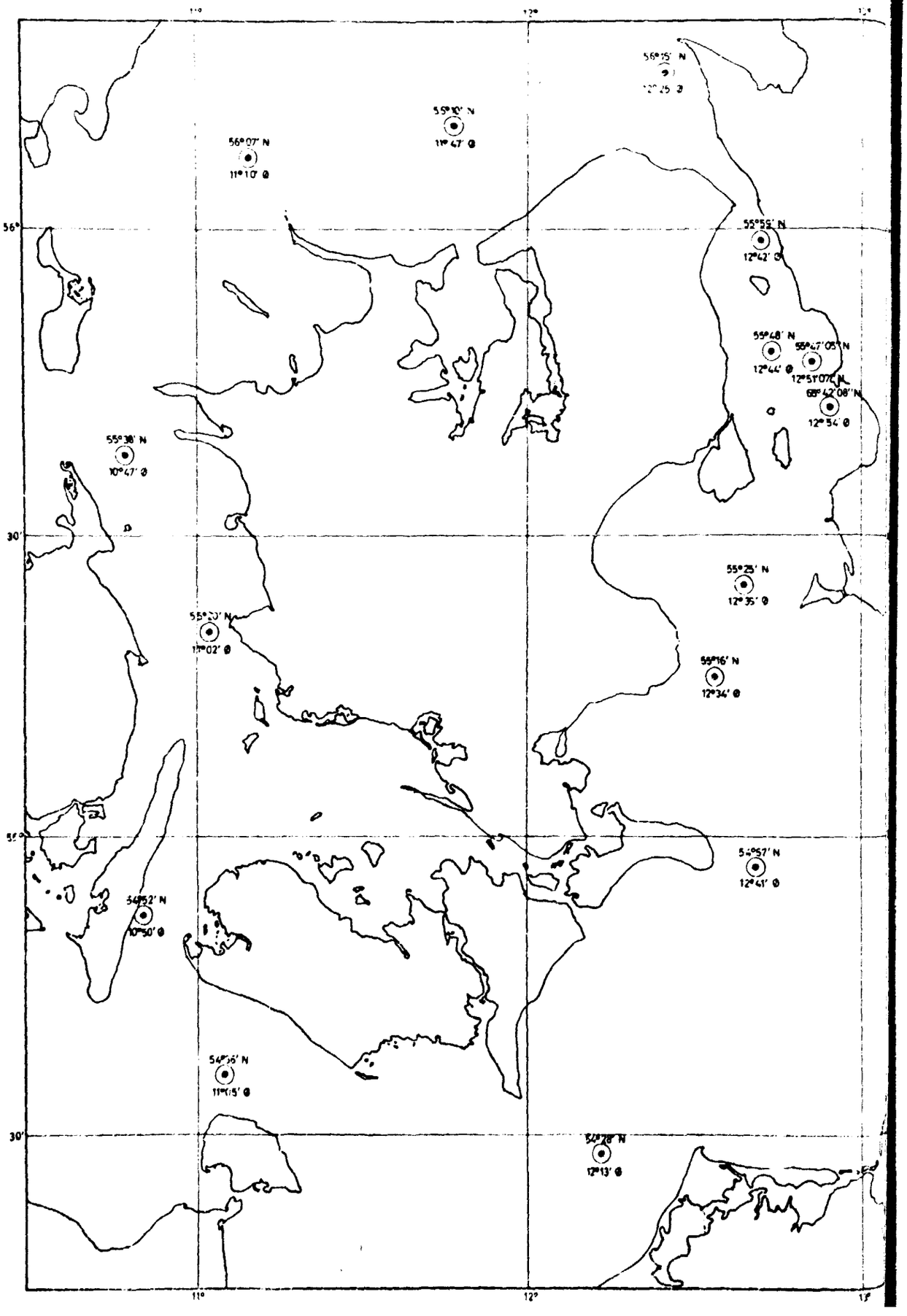
Strontium-90 and Caesium-137 in sea water collected at Ringhals in 1973

Position		September			
N	E	depth in m	^{90}Sr pCi/l	^{137}Cs pCi/l	Salinity o/oo
57°12'08"	11°50'07"	0	0.60	0.84	20.9
- " -	- " -	36	0.43	0.99	33.2
57°13'03"	12°03'04"	0	0.73	1.09	21.0
- " -	- " -	26	0.60	1.04	31.6
56°16'05"	12°06'	0	0.33	0.93	21.0
- " -	- " -	17	0.45	1.07	32.2
Mean		Surface	0.55	0.93	21.0
SD			0.20	0.10	0.1
SE			0.12	0.05	0.0
Mean		Bottom	0.49	1.03	32.3
SD			0.09	0.04	0.8
SE			0.05	0.02	0.5

Table 7.4

Strontium-90 and Caesium-137 in surface sea water collected in the North Sea, Skagerak and Kattegat in February 1973

Position	^{90}Sr pCi/l	^{137}Cs pCi/l	Salinity o/oo
56°57'N 07°31'E	0.55	0.85	34.4
57°40'N 10°00'E	0.48	0.83	28.6
54°57'N 07°26'E	0.43	1.23	33.6
55°50'N 05°46'E	0.48	0.76	34.2
55°19'N 04°48'E	0.47	1.02	34.2
54°52'N 01°10'E	0.40	1.00	34.4
56°14'N 06°34'E	0.23	0.90	34.2
56°14'N 12°07'E	0.53	0.94	23.2
57°11'N 01°09'W	1.39	3.09	34.4
57°41'N 02°55'E	0.63	1.25	34.5
Mean	0.56	1.19	32.6
SD	0.31	0.69	3.7
SE	0.10	0.22	1.2



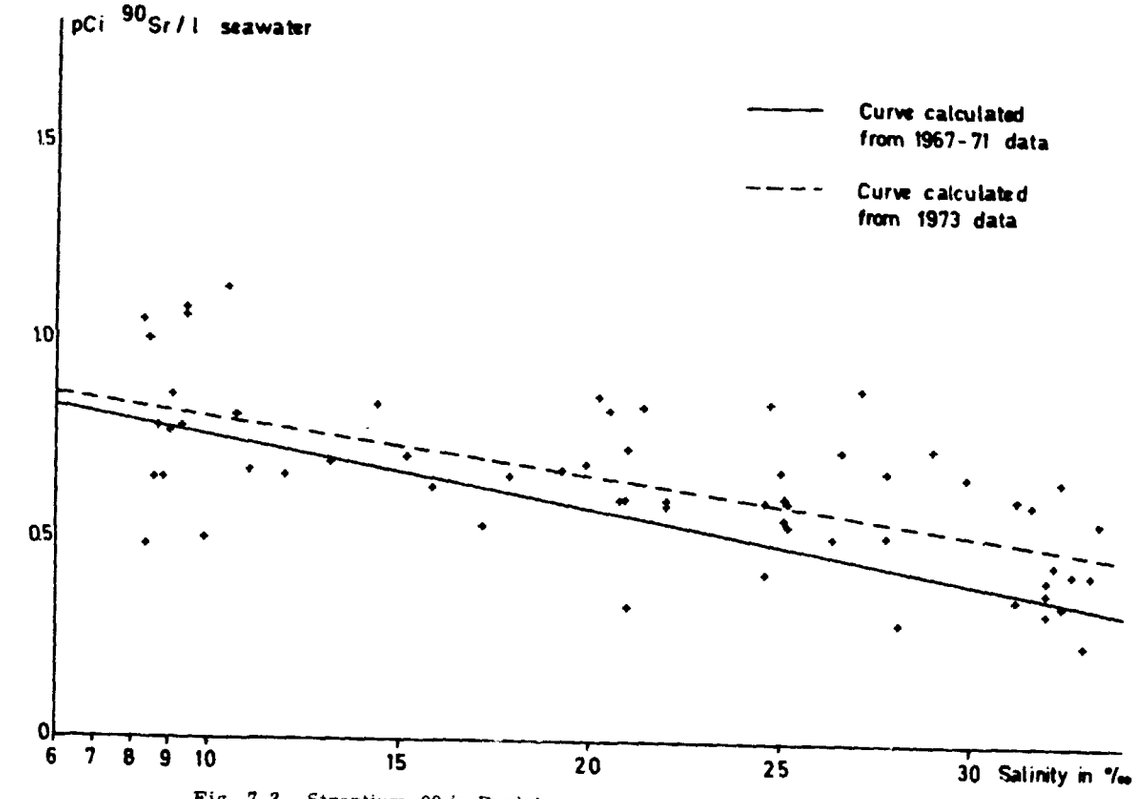


Fig. 7.3. Strontium-90 in Danish sea-water related to salinity (+ observed values in 1973)

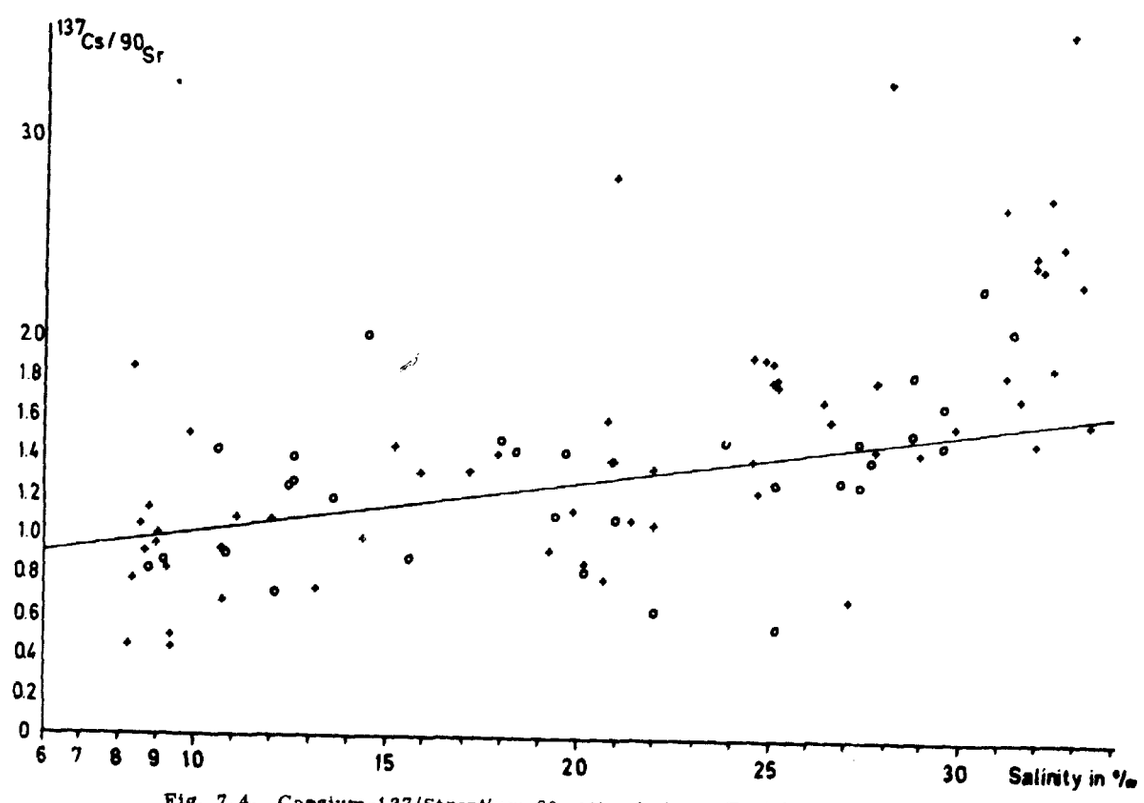


Fig. 7.4. Caesium-137/Strontium-90 ratios in inner Danish waters in 1972 (o) and in 1973 (+) related to salinity

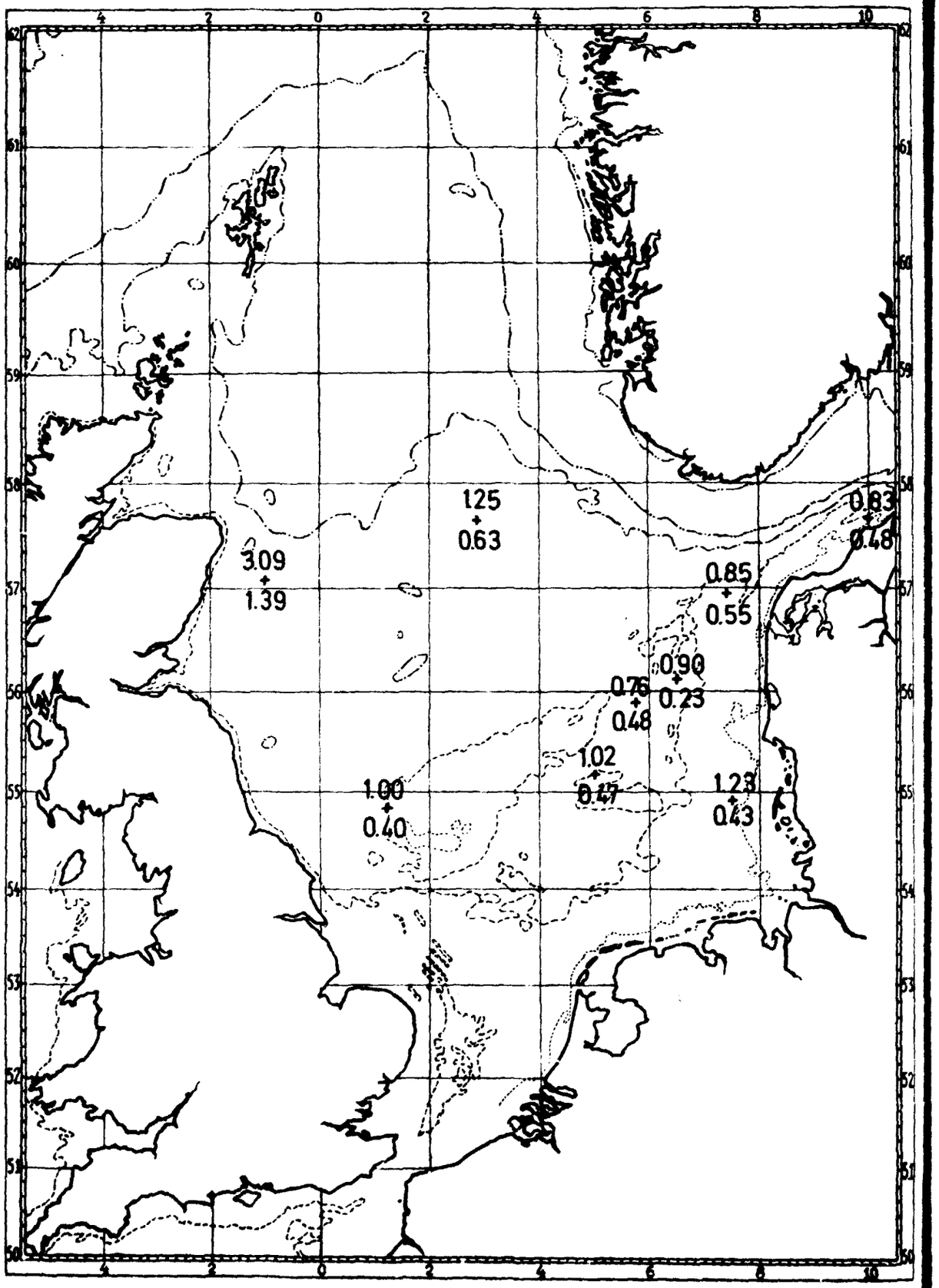


Fig. 7.5. Caesium-137 (upper figure) and Strontium-90 (lower figure) in surface sea water collected in the North Sea in February 1973.

Table 7.4 shows the levels in some sea water samples collected in February by the DANA in the North Sea. Fig. 7.5 is a map showing the sampling locations. As compared with collecting in September 1972[1], when samples were collected from the Northern part of the North Sea close to Scotland, this year samples were obtained from the more central parts of the North Sea. The highest levels were found in the sample closest to Scotland. The $^{137}Cs/^{90}Sr$ ratios were greater than two in half of the samples. This we take as an indication of a general radioactive pollution of the entire North Sea from sources other than nuclear weapons tests. British investigations[20] have shown that Windscale is probably mainly responsible for the high ^{137}Cs concentrations in Scottish waters. A current from the Irish Sea runs north and turns clockwise around Scotland. British measurements from March 1973 show the same ^{137}Cs level, i.e. 3 pCi $^{137}Cs/l$, off Aberdeen as we found in February.

8. SPECIAL SURVEYS

8.1. Meteorological Mast Experiment

As in previous years, samples of precipitation were collected from the meteorological mast at Risø at eight different heights. The ^{90}Sr analyses were carried out on half yearly samples.

Table 8.1.1 shows the ^{90}Sr levels in the eight bottles throughout the year. We may notice the same tendency as observed earlier: The ^{90}Sr concentration increases with increasing altitude.

The mean amount of precipitation in the eight bottles on the mast was 488 mm in 1973, i.e. 88% of the level measured in rain bottles at ground level at Risø (cf. table 3.2.4.1). The total deposition was 0.15 mCi $^{90}Sr/km^2$, i.e. 53% higher than the level measured at the ground stations at Risø (cf. 3.2.4).

Table [illegible]

Strontium-90 in the meteorological mast 1973

	3 m		7 m		23 m		39 m	
	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
Jan.-June	0.41	[illegible]	0.40	0.078	0.49	0.099	0.55	0.103
July-Dec.	0.17	0.058	0.21	0.067	0.19	0.061	0.18	0.055
1973	$\bar{x}$ 0.26	Σ 0.141	$\bar{x}$ 0.28	Σ 0.145	$\bar{x}$ 0.31	Σ 0.160	$\bar{x}$ 0.32	Σ 0.158
	537 mm		515 mm		523 mm		502 mm	

55 m		72 m		96 m		123 m		Mean	
pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2	pCi/l	mCi/km^2
0.48	0.087	0.47	A0.089	A0.48	0.075	0.61	0.087	0.49	0.085
A0.20	0.067	0.26	0.082	0.19	0.056	0.29	0.075	0.23	0.065
$\bar{x}$ 0.30	Σ 0.154	$\bar{x}$ 0.36	Σ 0.171	$\bar{x}$ 0.29	Σ 0.131	$\bar{x}$ 0.39	Σ 0.182	$\bar{x}$ 0.31	Σ 0.150
516 mm		505 mm		446 mm		364 mm		488 mm	

8.3. Human Milk

No human milk samples were collected in 1973.

8.4. Country-wide Measurement of the γ-Background in 1973

8.4.1. State Experimental Farms

As in previous years[1], the γ-background was measured in March, June, September, and December at ten State experimental farms. Table 8.4.1.1 shows the results, and table 8.4.1.2 gives the analysis of variance. The variations between locations as well as between months were highly significant

Table 8.4.1.1

γ-background at the state experimental farms in 1973 (μR/h)

	Mar.	June	Oct.	Dec.	Mean
Tylstrup	4.9±0.0	(5.7)	5.6±0.1	5.1±0.0	(5.3)
Studsgård	3.6±0.0	3.8±0.0	4.6±0.1	4.3±0.1	4.1
Ødum	5.0±0.0	(6.4)	6.5±0.1	6.0±0.1	(6.0)
Askov	4.8±0.0	6.1±0.1	6.2±0.0	6.0±0.1	5.8
St. Jyndevad	3.2±0.1	3.9±0.1	*4.0±0.0	3.9±0.1	3.8
Blangstedgård	5.8±0.1	6.7±0.1	6.7±0.1	6.6±0.1	6.4
Tystofte	6.3±0.0	9.0±0.5	7.1±0.1	6.7±0.1	7.3
Virumgård	6.1±0.1	7.0±0.1	(6.6)	6.1±0.1	(6.4)
Ledreborg	6.2±0.1	*7.8±0.0	6.5±0.1	(6.7)	(6.8)
Abed	6.3±0.1	6.4±0.1	6.0±0.4	6.1±0.1	6.2
Akirkeby	(7.7)	8.8±0.0	(8.5)	(8.3)	(8.3)
Mean	(5.4)	(6.5)	(6.2)	(6.0)	6.0

The error term is the S.E. of the mean of 6 determinations except * which were based on 2 determinations.

Table 8.4.1.2

Analysis of variance of the γ-background at the state experimental farms in 1973 (from table 8.4.1.1)

Variation	SSD	f	s^2	v^2	P
Between locations	286.414	10	28.6414	22.28	>99.95%
Between months	30.429	3	10.1431	7.89	>99.9%
Loc. x months	29.573	23	1.2858	11.46	>99.95%
Remainder	20.121	179	0.1124		

(P > 99.95%). As in previous years, it was evidently not the fall-out that determined the variation between locations. The mean level in 1973 was equal to that in 1972.

Fig. 8.4 shows the γ-background in four groups of sampling stations since 1962. The fact that stations with a low fall-out rate and a high clay content in the soil (Abed, Blangstedgård, and Tystofte) show higher γ-levels than stations with a high fall-out rate and a low clay content (but a high sand content) (Studsgård, St. Jyndevad, and Askov) was discussed in Risø Report No. 154[1].

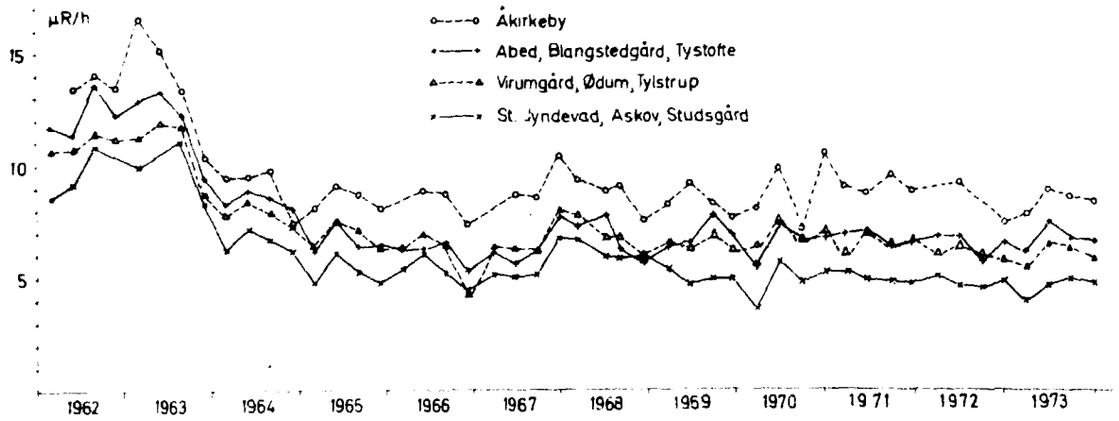


Fig. 8.4. The γ-background in the State experimental farms, 1962-73

8.4.2. The Risø Environment

γ-background measurements were performed in the five zones round Risø in July. The measurements were carried out at the locations where grass and soil are collected (cf. figs. 3.1.2.1 and 3.1.2.2 (the coloured map)).

Table 8.4.2 shows the results.

At all locations in zone I especially at the waste treatment station and at location 2 in zone II the γ-background shows increased levels because of the various radiation sources at the research establishment. The weighted annual mean for zones III-V was 6.5 µR/h. In zone I the surplus activity from the research establishment was 18.0 - 6.5 = 11.5 µR/h (in 1967: 4.0, in 1968: 3.9, in 1969: 3.3, in 1970: 4.7, in 1971: 1.6, and in 1972: 5.0). A man working in the open in the Risø area 40 hours a week for 45 weeks a year would thus get a surplus dose of 21 mR/year.

Table 8.4.2

γ-background (µR/h) in the five zones around Risø in 1973

Risø zone (cf. coloured map)	Location	Mar.	Apr.	May	July	Aug.	Sept.	Oct.	Nov.	Mean
I	1	6.3	6.7	8.0	10.4	14.4	8.5	7.1	6.9	8.5
-	2	8.5	9.1	9.1	10.2	10.4	10.2	9.2	8.7	9.4
-	3	37.6	49.6	35.4	41.8	50.3	55.0	43.2	43.2	44.4
-	4	11.8	11.3	10.2	10.6	12.5	12.5	11.1	11.6	11.4
-	5	14.2	14.6	14.6	16.8	16.1	18.4	19.1	17.2	16.4
Mean		15.7	18.1	15.5	18.0	20.7	20.9	17.9	17.5	18.0
II	1	5.2		5.2	8.3		6.9	6.2	6.4	6.4
-	2	7.8		7.6	9.0		8.0	8.3	8.3	8.2
-	3	5.6		5.6	7.3		6.6	6.2	6.4	6.3
-	4	5.4		5.6	7.1		6.6	7.1	6.6	6.4
Mean		6.0		6.0	7.9		7.0	7.0	6.9	6.8
III	1	6.1		6.1	8.0		7.3	7.6	7.3	7.1
-	2	5.8		5.4	7.6		6.6	6.9	6.6	6.5
-	3	5.6		5.8	7.8		6.9	6.9	6.9	6.6
-	4	5.4		5.6	7.1		6.9	6.2	6.4	6.3
Mean		5.7		5.7	7.6		6.9	6.9	6.8	6.6
IV	1			5.8		7.3		6.6	6.4	6.5
-	2			6.1		6.6		7.1	6.9	6.7
-	3			5.3		6.9		6.2	6.2	6.4
-	4			5.6		6.6		6.6	6.4	6.2
-	5			5.6		6.9		6.6	6.4	6.1
-	6			5.8		6.9		6.2	6.2	6.0
-	7			6.1		6.9		6.4	6.2	6.4
-	8			5.6		6.9		7.1	6.6	6.6
Mean				5.8		6.6		6.6	6.4	6.4
V	1			5.6		6.6		6.7	6.9	6.2
-	2			5.8		6.9		6.4	6.6	6.4
-	3			5.6		6.4		7.1	6.9	6.5
-	4			6.1		6.6		6.4	6.6	6.4
-	5			6.1		7.1		7.1	7.1	6.8
-	6			6.1		7.1		5.9	6.2	6.3
-	7			5.4		7.1		7.3	7.1	6.7
-	8			6.1		6.6		7.1	6.9	6.7
-	9			5.8		6.2		7.1	6.8	6.5
-	10			5.4		6.6		5.9	6.2	6.0
-	11			5.8		6.9		6.6	6.4	6.4
-	12			5.8		6.9		6.9	6.4	6.5
Mean				5.8		6.8		6.6	6.7	6.5

8.4.3. A Location in Zealand

As it is important to have knowledge of the preoperational radiation levels before a nuclear power plant goes critical, it was in 1967 decided to initiate such measurements at a location in Zealand (and one in Jutland) the neighbourhood of which might be used for nuclear power plants in the future.

The area around the location was divided into four zones: A, B, C,and D, with radii of 5, 10, 15, and 20 km respectively. The zones were each divided into 12 30° sectors, sector 1 being from due north and 30° clockwise, sector 2 from 30 to 60°, and so on. A measuring location was thus determined by a zone letter and a sector number. Locations in the sea were omitted.

Table 8.4.3 shows the results. The annual mean for all locations was 6.4 μR/h, i.e. nearly equal to the level found in zones III-V around Risø.

Table 8.4.3

γ-background (μR/h) around a location in Zealand in 1973

Zone and sector	Oct.
A 2	5.4
A 3	5.4
A 4	5.0
A 5	7.6
A 6	7.1
A 7	6.6
A 8	7.3
A 9	6.2
Mean	6.3
B 1	7.8
B 2	6.9
B 3	6.9
B 4	5.9
B 5	7.1
B 6	6.6
B 7	5.9
B 8	6.2
B 9	6.9
B 10	6.9
Mean	6.7

Zone and sector	Oct.
C 1	4.5
C 2	4.7
C 3	5.7
C 4	6.4
C 5	7.1
C 6	7.1
C 7	6.6
C 8	7.1
C 9	6.4
C 10	7.3
C 11	6.9
C 12	5.4
Mean	6.3
D 2	8.0
D 3	6.9
D 4	5.7
D 5	6.6
D 6	7.1
D 7	6.4
D 8	7.6
D 9	5.4
D 10	5.4
D 11	6.4
D 12	6.7
Mean	6.3

8.4.4. A Location in Jutland

Table 8.4.4 shows a similar investigation as in 8.4.3 for a location in Jutland. The annual mean for all locations was 6.1 μR/h, i.e. nearly equal to the levels of Zealand (cf. 8.4.2 and 8.4.3).

Table 8.4.4

γ-background (μR/h) around a location in Jutland in 1973

Zone and sector	Oct.
A 1	6.6
A 2	6.6
A 3	7.1
A 4	5.0
A 5	7.1
A 6	4.7
A 7	5.4
A 8	5.0
A 9	5.2
A 10	6.9
A 11	6.2
A 12	6.4
Mean	6.0
B 1	5.1
B 2	6.4
B 3	5.7
B 4	8.0
B 5	6.9
B 6	6.6
B 7	5.9
B 8	6.6
B 9	6.2
B 10	5.9
B 11	6.2
B 12	6.9
Mean	6.4

Zone and sector	Oct.
C 1	6.2
C 2	6.6
C 3	4.7
C 4	7.1
C 5	6.9
C 6	5.7
C 7	6.6
C 8	6.1
C 9	5.9
C 10	5.0
C 11	5.7
C 12	6.6
Mean	6.1
D 1	7
[illegible]	[illegible]
D 3	5.7
[illegible]	[illegible]
D 5	5.0
[illegible]	[illegible]
D 7	5.9
D 8	[illegible]
D 9	[illegible]
D 10	5.9
D 11	6.7
D 12	6.2
Mean	5.9

8.4.5. The Coasts of the Great Belt

The Great Belt is a main shipping route for international traffic through inner Danish waters. Occasionally this waterway will be passed by nuclear ships. An environmental γ-survey of the coastline along the Great Belt is therefore performed. Table 8.4.5 shows the results. The levels were mostly a little lower than those found in most of the other parts of the country. The annual mean was 6.1 μR/h, i.e. equal to that found in 1972.

Table 8.4.5

The γ-background (μR/h) along the coasts of the Great Belt in 1973

Location	October
Agersø	4.5
Omø	5.2
Røsnæs	6.4
Reersø	5.4
Halskov	6.4
Knudshoved	5.4
Risinge	5.9
Fyns Hoved	5.9
Tårup Strand	6.2
Langeland N.	5.9
Tranekær	6.2
Vindeby Strand	6.9
Kelds Nor	8.5
Mean	6.1

9. CONCLUSION

9.1. Risø Environmental Monitoring

No radioactive contamination of the environment originating from the operation of the research establishment was ascertained outside Risø in 1973. As in previous years, the variations in contamination level were independent of the distance of the sampling locations from Risø.

9.2. Nuclear-Weapon Debris in Air, Precipitation, Soil, Ground Water, and Surface Water

The mean content of ^{90}Sr in air collected in 1973 was 0.0004 pCi $^{90}Sr/m^3$, i.e. half of the 1972 level. The average fall-out at the State experimental farms in 1973 was 0.19 mCi $^{90}Sr/km^2$ or approx. 45% of the 1972 figure, and the mean concentration of ^{90}Sr in rain water was 0.31 pCi $^{90}Sr/l$.

By the end of 1973 the accumulated fall-out down to a depth of 30 cm was approx. 51 mCi $^{90}Sr/km^2$. The corresponding ^{137}Cs was measured at 97 mCi/km^2.

In agreement with the greater amounts of precipitation in that part of the country the fall-out levels in Jutland were 15-25% higher than the levels found in eastern Denmark.

The median level of ^{90}Sr in Danish ground water was 0.006 pCi $^{90}Sr/l$.

9.3. Strontium-90 and Caesium-137 in the Human Diet

The mean level of ^{90}Sr in Danish milk was 4.7 S.U., and the mean content of ^{137}Cs was approx. 6 pCi $^{137}Cs/l$.

The 1973 ^{90}Sr and ^{137}Cs levels were 30-50% lower than the levels found in milk produced in 1972.

The ^{90}Sr mean content in grain from the 1973 harvest was 25 pCi $^{90}Sr/kg$. The ^{137}Cs mean content in grain was 10 pCi $^{137}Cs/kg$. The ^{90}Sr level in grain from the 1973 harvest was 2/3 of the level found in the 1972 harvest, and ^{137}Cs was approx. 2/5 of the 1972 level.

The mean contents of ^{90}Sr and ^{137}Cs in Danish vegetables collected in 1973 were 9 pCi $^{90}Sr/kg$ (27 S.U.) and 2.1 pCi $^{137}Cs/kg$ respectively, and in fruits 3.8 pCi $^{90}Sr/kg$ and 3 pCi $^{137}Cs/kg$; potatoes contained 3.9 pCi $^{90}Sr/kg$ and 5 pCi $^{137}Cs/kg$.

The mean levels of ^{90}Sr and ^{137}Cs in total-diet samples collected in 1973 were 7.3 S.U. or 12.6 pCi ^{90}Sr/day and 17 pCi ^{137}Cs/day respectively. From analyses of the individual diet components the ^{90}Sr level in the Danish average diet was estimated to be 5.9 S.U. and the ^{137}Cs intake to be 15 pCi ^{137}Cs/day. The ^{90}Sr levels in the Danish total diet consumed in 1973 were 10-20% lower than the 1972 levels, while the ^{137}Cs levels were 50% lower.

Grain products contributed 34% and milk products 35% to the total ^{90}Sr intake, and 21% of the ^{137}Cs in the diet came from meat, 25% from grain products, and 19% from milk products.

The ^{90}Sr as well as the ^{137}Cs diet levels were on the average significantly higher in Jutland than in eastern Denmark.

9.4. Strontium-90 and Caesium-137 in Humans

The ^{90}Sr mean content in human bone (vertebrae) collected in 1973 was 2.1 S.U. in new-born children, 1.8 S.U. in infants, 1.6 S.U. in children and teen-agers, 1.5 S.U. in adults (20-29 years old), and 1.7 S.U. in adults of more than 29 years. The 1973 bone levels were generally a little lower than the 1972 levels.

The mean content of ^{137}Cs in the human body in 1973 was estimated from whole-body countings to be 1.5 nCi (11 pCi ^{137}Cs/g K), somewhat lower than the 1972 level.

9.5. Strontium-90 in Sea Water

The mean content of ^{90}Sr in inner Danish surface waters was approx. 0.75 pCi ^{90}Sr/l in 1973, i.e. probably a little higher than the levels in previous years. The ^{137}Cs concentration was approx. 1.1 times the ^{90}Sr concentration in surface water collected in the inner Danish waters (mean salinity 15 o/oo).

9.6. The γ-Background

The γ-background measured at the State experimental farms in 1973 was 6.0 μR/h, which is unchanged from last year.

9.7. Summary

Neither in 1971 nor in 1972 thermonuclear atmospheric tests were carried out in the Northern hemisphere. All levels which mostly depend upon the activity in the atmosphere have consequently shown a marked decrease since 1971.

The concentrations of long-lived fall-out nuclides in ground-level air and precipitation collected in 1973 were 40-50% of the levels found in 1972.

In milk produced in 1973 the ^{90}Sr and ^{137}Cs levels were 30-50% lower than the 1972 levels. In grain from 1973 the levels were 50-70% of those in 1972.

The ^{90}Sr levels in the total diet consumed in 1973 were probably a little lower than the 1968-72 levels. The ^{137}Cs levels were definitely lower than those of the previous years.

The ^{90}Sr concentrations in human bone were only a little lower in 1973 than in 1972.

APPENDIX A

Calculated Fall-out in the Eight Zones in 1973

Zone		mm precipitation in 1973	mCi $^{90}Sr/km^2$ in 1973	Accumulated mCi $^{90}Sr/km^2$ by the end of 1973 (0-30 cm)
I:	N. Jutland	662	0.20	55
II:	E. Jutland			
III:	W. Jutland			
IV:	S. Jutland			
V:	Funen	560	0.18	46
VI:	Zealand			
VII:	Lolland-Falster			
VIII:	Bornholm	558	0.20	48
Area-weighted mean		630	0.20	52

The amounts of precipitation were obtained from ref. 9, and from 4.1 and 4.2.

APPENDIX B

Statistical information

Zone		Area in km^2 15) 1971	Population in thousands 15) 1971	Annual milk production in mega-kg 14) 1971	Annual wheat production in mega-kg 13) 1972	Annual rye production in mega-kg 13) 1972	Annual potato production in mega-kg 13) 1972	Vegetable area in km^2 13) 1972
I:	N. Jutland	6,171	457	911	145	155	609	14
II:	E. Jutland	7,561	841	1,258				
III:	W. Jutland	12,104	661	926				
IV:	S. Jutland	3,929	239	572				
V:	Funen	3,486	434	393	448	71	100	73
VI:	Zealand	7,435	2,148*	395				
VII:	Lolland-Falster	1,795	125	68				
VIII:	Bornholm	588	47	39				
Total		43,069	4,950	4,662	593	226	709	87

* 1,345,000 people were living in Greater Copenhagen and 801,000 in the remaining part of Zealand.

APPENDIX C

In 1973 the agreement between predicted and observed ^{90}Sr levels was as in 1972 poor. The observed values were significantly greater than the predicted ones if the models from 1970-71 shown in table C1 were used. If the models from 1968[17] were applied the gap between observations and predictions was reduced markedly. As regards ^{137}Cs the agreement between observations and predictions was in some cases better than for ^{90}Sr

Table C 1

A comparison between observed and predicted ^{90}Sr levels in the human food chain in Denmark in 1973

Sample and location	Observed	Predicted	Equation used for the prediction	Predicted from 1968 models[17]
Milk from Jutland	5.6	5.0	$S.U. = 1.04d_{(i)} + 0.47d_{(i-1)} + 0.26A_{by(i-1)}$	7.3
Milk from the Islands	3.4	2.8	$S.U. = 0.78d_{(i)} + 0.47d_{(i-1)} + 0.18A_{by(i-1)}$	
Rye from Jutland	86	44	$S.U. = 204d_{(j-a)} + 2.06A_{by(i-1)}$	55
Rye from the Islands	40	20	$S.U. = 156d_{(j-a)} + 1.20A_{by(i-1)}$	
Barley from Jutland	61	44	$S.U. = 161d_{(j-a)} + 2.14A_{by(i-1)}$	60
Barley from the Islands	23	19	$S.U. = 94d_{(j-a)} + 1.24A_{by(i-1)}$	
Wheat from Jutland	83	60	$S.U. = 154d_{(j-a)} + 3.14A_{by(i-1)}$	74
Wheat from the Islands	34	34	$S.U. = 136d_{(j-a)} + 2.24A_{by(i-1)}$	
Oats from Jutland	56	31	$S.U. = 70d_{(j-a)} + 1.60A_{by(i-1)}$	40
Oats from the Islands	26	15	$S.U. = 56d_{(j-a)} + 0.96A_{by(i-1)}$	
Potatoes from Jutland	4.3	1.9	pCi $^{90}Sr/kg = 0.13d_{(i)} + 0.11A_{by(i-1)}$	3.2
Potatoes from the Islands	3.4	0.9	pCi $^{90}Sr/kg = 0.18d_{(i)} + 0.062A_{by(i-1)}$	
Total diet from Jutland	8.3	4.7	$S.U. = 0.89d_{(i)} + 1.26d_{(i-1)} + 0.25A_{by(i-1)}$	7.3
Total diet from the Islands	6.9	3.6	$S.U. = 0.84d_{(i)} + 1.27d_{(i-1)} + 0.21A_{by(i-1)}$	
Newborns' bone	2.1	0.7	$S.U. = 0.164d_{\frac{i+(i-1)}{2}} + 0.017d_{(i-2)} + 0.037A_{by(i-1)}$	1.2
Adults' vertebrae	1.6	0.9	$S.U. = 0.021d_{\frac{i+(i-1)}{2}} + 0.039d_{(i-2)} + 0.056A_{by(i-1)}$	1.8

The prediction models were calculated from data collected in 1962-1970 (for grain 1962-1971)

d is the fall-out rate in mCi $^{90}Sr/km^2$ (table 4.1.1). A is the estimated, available, accumulated fall-out in mCi $^{90}Sr/km^2$ calculated for an effective half-life of ^{90}Sr in the soil of 4 years.

(i) is the current year, (i-1) the year before etc. (j-a) is July-August.

for the 1971 models (table C2) as well as for the 1968 models[17], but for potatoes, beef and oats the agreement was poor.

We feel confident that the ^{90}Sr in the soil is not made unavailable as fast as we thought in 1971[1] (i.e. with an effective half life of 4 years). We also suspect some ^{137}Cs to be taken up from the soil through the roots, e.g. in the case of potatoes.

Table C 2

A comparison between observed and predicted ^{137}Cs levels in the human food chain in Denmark in 1973

Sample and location	Observed	Predicted	Equation used for the prediction	Predicted from 1968 models[17]
Milk from Jutland	4.6	2.3	pCi $^{137}Cs/g\ K = 4.45d_{(i)} + 1.47d_{(i-1)} + 0.39d_{(i-2)}$	4.4
Milk from the Islands	2.1	1.1	pCi $^{137}Cs/g\ K = 2.53d_{(i)} + 1.63d_{(i-1)}$	
Rye from Jutland	18	12	pCi $^{137}Cs/kg = 131d_{(m-a)}$	10
Rye from the Islands	6	7	pCi $^{137}Cs/kg = 118d_{(m-a)}$	
Barley from Jutland	12	9	pCi $^{137}Cs/kg = 92d_{(m-a)}$	7
Barley from the Islands	4	5	pCi $^{137}Cs/kg = 83d_{(m-a)}$	
Wheat from Jutland	7	8	pCi $^{137}Cs/kg = 89d_{(m-a)}$	6
Wheat from the Islands	8	4	pCi $^{137}Cs/kg = 71d_{(m-a)}$	
Oats from Jutland	12	8	pCi $^{137}Cs/kg = 81d_{(m-a)}$	6
Oats from the Islands	12	4	pCi $^{137}Cs/kg = 73d_{(m-a)}$	
Potatoes from Jutland	6.6	1.2	pCi $^{137}Cs/kg = 5.6d_{(i)}$	1.0
Potatoes from the Islands	4.2	0.9	pCi $^{137}Cs/kg = 5.3d_{(i)}$	
Beef	18	9	pCi $^{137}Cs/kg = 37d_{(i)} + 5.2d_{(i-1)}$	42
Pork	23	22	pCi $^{137}Cs/kg = 37d_{(i)} + 17d_{(i-1)} + 5.2d_{(i-2)}$	24
Total diet from Jutland	17	17	pCi $^{137}Cs/day = 8.8d_{(i)} + 11d_{(i-1)} + 6.1d_{(i-2)}$	15
Total diet from the Islands	17	10	pCi $^{137}Cs/day = 7.3d_{(i)} + 11.3d_{(i-1)} + 3.2d_{(i-2)}$	
Whole body from the Islands	11	14	pCi $^{137}Cs/g\ K = 4.2d_{(i)} + 4.2d_{(i-1)} + 8.6d_{(i-2)}$	36

The prediction models were for milk calculated from the data collected 1962-1970, for grain 1962-1971, for potatoes 1963-1971, for meat, total diet and whole body 1963-1970.

(m-a) is May-August and the fall-out rates are measured in mCi $^{90}Sr/km^2$ (cf. also remarks to table C 1).

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